Public Document No. 31

TWENTY-SEVENTH ANNUAL REPORT

OF THE

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION.

PARTS I. AND II.,

BEING PARTS III. AND IV. OF THE FIFTY-SECOND ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL COLLEGE.

JANUARY, 1915.

ENDING THE THIRTY-SECOND YEAR FROM THE FOUNDING OF THE STATE AGRICULTURAL EXPERIMENT STATION.

BOSTON:
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Approved by

The State Board of Publication.

TWENTY-SEVENTH ANNUAL REPORT

OF THE

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION.

PART I.

REPORT OF THE DIRECTOR AND OTHER OFFICERS.

PART II.

DETAILED REPORT OF THE EXPERIMENT STATION.

A RECORD OF THE THIRTY-SECOND YEAR FROM THE FOUNDING OF THE STATE AGRICULTURAL EXPERIMENT STATION.

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PART I.

Part II.

Massachusetts Agricultural Experiment Station.

OFFICERS AND STAFF.

COMMITTEE.

STATION STAFF.

Administration.

William P. Brooks, Ph.D., *Director*.
Joseph B. Lindsey, Ph.D., *Vice-Director*.
Fred C. Kenney, *Treasurer*.
Charles R. Green, B.Agr., *Librarian*.
Mrs. Lucia G. Church, *Clerk*.
Miss Grace E. Gallond, *Stenographer*.

Agricultural Economics.

Alexander E. Cance, Ph.D., *Agricultural Economist*.

Agriculture.

William P. Brooks, Ph.D., *Agriculturist*.
Henry J. Franklin, Ph.D., *In Charge Cranberry Substation*.
Edwin F. Gaskill, B.Sc., *Assistant Agriculturist*.
Robert L. Coffin, *Assistant*.

Chemistry.

Joseph B. Lindsey, Ph.D., *Chemist*.
Edward B. Holland, Ph.D., *Associate Chemist in Charge* (*Research Section*).
Fred W. Morse, M.Sc., *Research Chemist*.
Henri D. Haskins, B.Sc., *Chemist in Charge* (*Fertilizer Section*).
Philip H. Smith, M.Sc., *Chemist in Charge* (*Food and Dairy Section*).
Lewell S. Walker, B.Sc., *Assistant Chemist*.
Rudolf W. Ruprecht, M.Sc., *Assistant Chemist*.
Carleton P. Jones, B.Sc., *Assistant Chemist*.
Walter S. Frost, B.Sc., *Assistant Chemist*.
James P. Buckley, Jr., *Assistant Chemist*.
James T. Howard, *Inspector*.
Harry L. Allen, *Assistant in Laboratory*.
James R. Alcock, *Assistant in Animal Nutrition*.
Miss Alice M. Howard, *Clerk*.
Miss Rebecca L. Mellor, *Clerk*.

Entomology.	HENRY T. FERNALD, Ph.D., *Entomologist.* BURTON N. GATES, Ph.D., *Apiarist.* ARTHUR I. BOURNE, A.B., *Assistant Entomologist.* Miss BRIDIE E. O'DONNELL, *Clerk.*
Horticulture.	FRANK A. WAUGH, M.Sc., *Horticulturist.* FRED C. SEARS, M.Sc., *Pomologist.* JACOB K. SHAW, Ph.D., *Research Pomologist.* JOHN B. NORTON, B.Sc., *Graduate Assistant.*
Meteorology.	JOHN E. OSTRANDER, A.M., C.E., *Meteorologist.* R. E. MCLAIN, *Observer.*
Microbiology.	CHARLES E. MARSHALL, Ph.D., *Microbiologist.* F. H. HESSELINK VAN SUCHTELEN, Ph.D., *Research Microbiologist.*
Poultry Husbandry.	JOHN C. GRAHAM, B.Sc., *Poultry Husbandman.* HUBERT D. GOODALE, Ph.D., *Research Biologist.* Miss MARCELLA C. CURRY, *Clerk.*
Vegetable Physiology and Pathology.	GEORGE E. STONE,[1] Ph.D., *Vegetable Physiologist and Pathologist.* A. VINCENT OSMUN, M.Sc., *Acting Head of Department.* GEORGE H. CHAPMAN, M.Sc., *Research Vegetable Physiologist.* ORTON L. CLARK, B.Sc., *Assistant Vegetable Physiologist and Pathologist.*
Veterinary Science.	JAMES B. PAIGE, B.Sc., D.V.S., *Veterinarian.* GEORGE E. GAGE, Ph.D., *Research Pathologist.* Miss BERYL H. PAIGE, A.B., *Assistant.*

[1] On leave.

REPORT OF THE DIRECTOR.

WM. P. BROOKS.

ADMINISTRATION.

Station Staff.

During the past year but few changes occurred in station staff, and none in the personnel in the positions of chief responsibility. The following should be mentioned: —

The place of Chas. E. Ward in the trustees' committee on the experiment station, made vacant by his resignation in August, was filled by the appointment of his successor on the Board of Trustees — Mr. Edmund Mortimer of Grafton — to membership in the experiment station committee.

Dr. J. B. Lindsey, vice-director and head of the department of chemistry, was granted leave of absence on account of ill health from June 20 until September 1, and during his absence Mr. F. W. Morse served as vice-director and Mr. E. B. Holland as head of the chemical department.

Dr. Geo. E. Stone was granted leave of absence on account of ill health in October, and this leave still continues. Prof. A. Vincent Osmun was appointed acting head of the department of vegetable physiology and pathology.

Mr. Geo. H. Chapman, after eight months' leave of absence for study and investigation abroad, resumed his duties on May 1. Mr. Orton L. Clark, employed in the department of vegetable physiology and pathology during Mr. Chapman's absence, was appointed assistant in the department on Dec. 1, 1913, taking the place of Mr. Edw. A. Larrabee, whose resignation took effect on February 28.

Mr. John W. Sayer, foreman in the experimental poultry yards, resigned September 30. His work is now carried on by Mr. Austin Brown, who has not, however, yet received formal appointment to the position of foreman.

Miss F. Ethel Felton, first clerk in the department of chemistry, resigned in August, and Miss A. M. Howard was promoted to the position of first clerk. Since the promotion of Miss Howard, Miss Rebecca L. Mellor has given full time to the work of the department of chemistry.

R. E. McLain has succeeded E. K. Dexter as observer in the meteorological department.

Maintenance.

The most important change affecting the revenues of the experiment station during the past year has been the increase of $5,000 provided by act of Legislature in 1913. There is also a considerable increase in the receipts in the chemical department for analytical work, cow testing, etc., and in the amount received for analysis fees under the fertilizer law. On the other hand, the revenue from the sale of fruit from the cranberry bog in East Wareham, on account of relatively small yield and low prices, is about $3,000 less than in 1913. The total revenues are shown in the following table: —

Total Revenue for the Fiscal Year, Dec. 1, 1913, to Dec. 1, 1914.

State appropriation,	$20,000 00
Federal appropriations: —	
Hatch fund,	15,000 00
Adams fund,	15,000 00
Agricultural department, sales and labor,	2,494 49
Chemical department, analytical work, cow testing, etc.,	10,013 33
Fertilizer law, analysis fees,	11,112 00
Feed law, State appropriation,	6,000 00
Cranberry substation: —	
Sale of fruit,	2,511 86
Sale of vines,	17 50
Prizes,	10 00
Meteorological observations, scientific services, etc.,	137 50
Graves' orchard: —	
Sale of fruit,	129 25
Total,	$82,425 93

The aggregate total revenue exceeds the aggregate for the last year to the amount of $3,182.61. The total required in the execution of the feed and fertilizer laws amounted to

$15,272.66. These expenditures in detail are shown in subsequent pages. The total current revenue available for general administration and investigation, therefore, amounted to $67,153.27.

The treasurer's report in full will be found on pages 28 *a* and 29 *a*.

Fertilizer Law Account.

Dec. 1, 1913, to Nov. 30, 1914.

Balance Dec. 1, 1913,		$1,467 96	
Fertilizer fees,		11,112 00	
Total,			$12,579 96

Expenditures.

Collection expenses: —			
Inspector's salary,	$670 00		
Inspector's traveling expenses,	627 02		
		$1,297 02	
Salaries: —			
Chemists,	$5,446 68		
Clerical,	399 00		
		5,845 68	
Labor: —			
Miscellaneous (laboratory assistance),	$149 00		
Janitor,	153 44		
		302 44	
Chemicals and apparatus,		645 36	
Heat and light (gas),		136 51	
Laundry,		13 02	
Office supplies,		132 88	
Miscellaneous,		72 97	
Library,		6 00	
Publications: —			
Bulletin No. 147,	$794 27		
Mailing,	3 60		
		797 87	
Official traveling,		124 98	
Fertilizer experiments: —			
Labor and materials,	$326 80		
Rent,	25 00		
		351 80	
Total,			9,726 53
Balance Dec. 1, 1914,			$2,853 43

Feed Control Account.

Dec. 1, 1913, to Nov. 30, 1914.

Balance Dec. 1, 1913,		$916 07	
Appropriation,		6,000 00	
Total,			$6,916 07

Expenditures.

Collection expenses: —			
Inspector's time,	$330 00		
Inspector's traveling expenses,	377 40		
		$707 40	
Salaries (chemical and clerical),		3,448 30	
Labor (janitor),		94 95	
Heat and light,		38 38	
Laboratory apparatus,		154 14	
Chemicals,		74 72	
Office supplies,		40 85	
Expert service: —			
Legal,	$78 27		
Stenographic,	18 75		
		97 02	
Official traveling,		110 78	
Minor repairs,		18 14	
Sundries,		17 99	
Library,		5 00	
Publications: —			
Bulletin No. 146,	$565 71		
Control Bulletin No. 1,	469 00		
Mailing,	12 55		
		1,047 26	
Furniture and fixtures,		43 00	
Total,			5,897 93
Balance Dec. 1, 1914,			$1,018 14

Publication.

During the past year an important change has been made in the law governing the publication of the annual report of the experiment station. Up to the beginning of last year the law provided, briefly: for the publication of the report in two parts, — technical and general, — designated respectively as Part III. and Part IV. of the annual report of the college. The law provided for the printing by the State of 20,000 copies of Part III. (technical), of which 15,000 copies were to be bound with the report of the State Board of Agriculture, and for the printing of 16,000 copies of Part IV. (the general or popular part of the report), all of which were for the use of the trustees and were distributed by the station.

Besides the annual report of the station in two parts (which was printed by the State) the station published a series of bulletins, the cost of publication being covered by the use of general station funds.

The amended law, in so far as it relates to station publications, is as follows: —

SECTION 1. The annual report of the trustees of the Massachusetts agricultural college may be printed in four parts, namely, . . . part three to consist of the report of the director of the Massachusetts agricultural experiment station and other officers, and part four to consist of the detailed reports of the experiment station.

SECTION 2. . . . ; of part three there may be printed as many copies, not exceeding twenty thousand, as may be requested by the director of the experiment station for the use of said trustees; and of part four, which may be offered for publication in instalments to be known as bulletins, there may be printed as many copies of each instalment as shall be requested by the said director, but in no case to exceed twenty thousand copies, for the use of the said trustees; and in addition there may be printed for the use of the state board of agriculture as many copies of each instalment, not exceeding twenty-five hundred, as may be requested by the said board.

The law as it now stands brings the method of publication into conformity with that recommended by the Association of American Agricultural Colleges and Experiment Stations, and at the same time the new method secures a number of other important advantages: —

1. Results are published promptly in bulletin form instead of being held until the end of the year.

2. The size of the edition of each bulletin and report can be fixed by the director, and can, therefore, be much more closely adapted to the need than under the old law, which definitely specified the number. Under the new law editions have varied from 2,900 to 20,000.

3. As each bulletin is bound by itself it can be circulated with greater economy, being sent only to those specially interested in the subject-matter.

4. The new method avoids sending reports and bulletins in duplicate to individuals whose names are included in the mailing lists both of the station and the State Board of Agriculture, as must frequently have been done under the old law.

5. Under the new law the cost of publication of bulletins is borne by the State, instead of being provided for from the general funds of the station.

6. While securing all these advantages and relieving the station funds, as indicated under paragraph 5, the cost to the State is materially lessened under the new plan of publication. The cost to the State of the station publications during the first year under the new law was rather over $900 less than during the last year under the old law; while during the same period the saving to the station due to the printing of bulletins at State instead of station expense was more than $700.

The following is a complete list of the station publications for the fiscal year just ended: —

Annual Report.

Twenty-sixth annual report: Part I., 65 pages; Part II. (Bulletins Nos. 148–155), 190 pages; Combined Contents and Index, Parts I. and II., 10 pages.

Bulletins.

No. 147. Inspection of Commercial Fertilizers, by H. D. Haskins, L. S. Walker, C. P. Jones and W. S. Frost; 96 pages.

No. 148. On the Diagnosis of Infection with Bacterium Pullorum in the Domestic Fowl, by Geo. Edward Gage; 20 pages.

No. 149. A Study of Variation in Apples, by J. K. Shaw; 16 pages.

No. 150. Reports on Experimental Work in Connection with Cranberries, by H. J. Franklin and F. W. Morse; 32 pages.

No. 151. The Determination of Acetyl Number, by Edw. B. Holland; 10 pages.

No. 152. The Digestibility of Cattle Foods, by J. B. Lindsey and P. H. Smith; 42 pages.

No. 153. A Summary of Meteorological Records, by J. E. Ostrander; 26 pages.

No. 154. Alfalfa, by Wm. P. Brooks; 25 pages.

No. 155. Composition and Use of Some of the New Fertilizer Materials; also Fertilizing Value of Some Local By-Products, by H. D. Haskins; and Coccanut Meal, by J. B. Lindsey; 18 pages.

Control Series Bulletin No. 1. Inspection of Commercial Feed Stuffs, by P. H. Smith and C. L. Beals; 61 pages.

Circulars.

No. 36. Poultry Manures, their Treatment and Use, by Wm. P. Brooks; revision of No. 35; 4 pages.

No. 37. Green Manuring and Cover Crops, by Wm. P. Brooks; 6 pages.

No. 38. Cabbage, Cauliflower, Turnip, Rape and Other Crucifers, by Wm. P. Brooks; 4 pages.

No. 39. Lime and Sulfur Solutions, by G. E. Stone; 4 pages.

No. 40. Downy Mildew of Cucumbers, by G. E. Stone; 2 pages.

No. 41. The Control of Onion Smut, by G. E. Stone; 4 pages.

No. 42. Fertilizers for Potatoes, by Wm. P. Brooks; revision of No. 26; 4 pages.

No. 43. Cutworms, by H. T. Fernald; revision of No. 2; 2 pages.

No. 44. Suggestions for Judging the Agricultural Value and Adaptation of Land, by Wm. P. Brooks; 8 pages.

No. 45. The Chemical Analysis of Soils, by Wm. P. Brooks; revision of No. 29; 4 pages.

No. 46. Directions for sending Fruits for Identification, by J. K. Shaw; 4 pages.

Reprint State Board of Agriculture Publications.

The Care, Feeds and Feeding of the Dairy Cow, by J. B. Lindsey; 30 pages.

Apple Diseases, by G. E. Stone; 19 pages.

Connecticut Agricultural Experiment Station.

Bulletin No. 180. Studies on the Tobacco Crop of Connecticut, by E. H. Jenkins; 65 pages.

Meteorological Reports.

Twelve numbers, 4 pages each.

The total number of copies of reports and bulletins issued during the last fiscal year was 97,400. In addition, 5,400 meteorological bulletins were printed and 19,500 copies of circulars, making a grand total of 122,300 copies of publications issued during the year.

Publications Available for Distribution.

Bulletins.

No. 33. Glossary of Fodder Terms.
No. 76. The Imported Elm-Leaf Beetle.
No. 115. Cranberry Insects.
No. 130. Meteorological Summary, Twenty Years (1889–1908).
Nos. 131, 135, 140. Inspection of Commercial Fertilizers, 1909–11.
Nos. 132, 136, 139, 142. Inspection of Commercial Feed Stuffs, 1910–12.
No. 133. Green Crops for Summer Soiling.
No. 134. The Hay Crop.
No. 144. The Relation of Light to Greenhouse Culture.
No. 148. On the Diagnosis of Infection with Bacterium Pullorum in the Domestic Fowl. (Technical.)
No. 150. Reports on Experimental Work in Connection with Cranberries.
No. 153. Summary of Meteorological Records, Twenty-five Years (1889–1913).
No. 154. Alfalfa.
No. 156. Electrical Injuries to Trees.[1]
No. 157. The Marguerite Fly.[1]
No. 158. The Nutritive Value of Certain Feeds.[1]
No. 159. The Technical Description of Apples.[1] (Technical.)
No. 160. Report of Cranberry Substation.
No. 161. The Effect on a Crop of Clover of Liming the Soil and Toxic Effect of Iron and Aluminum Salts on Clover Seedlings.
No. 162. Phosphates in Massachusetts Agriculture; Importance, Selection and Use.
Control Series, No. 1. Inspection of Commercial Feed Stuffs, 1914.
Control Series, No. 2. Inspection of Commercial Fertilizers, 1914.[1]
Separata. Composition and Digestibility of Fodder Articles.
Index to bulletins and reports previous to June, 1895 (Hatch Experiment Station).
Index to bulletins and reports, 1888 to 1907 (Hatch Experiment Station).
Index to bulletins and reports, 1883 to 1894 (State Agricultural Experiment Station).
Connecticut Experiment Station Bulletin No. 180. Studies on the Tobacco Crop of Connecticut, by E. H. Jenkins.

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[1] Bulletins Nos. 156 to 162 and Control Series No. 2 were not printed until after the end of the year covered by this report, but are here included as the date of printing the report is later than the dates of printing these bulletins.

Circulars.

No. 20. Lime in Massachusetts Agriculture.
No. 27. Seeding Mowings.
No. 42. Fertilizers for Potatoes.
No. 43. Cutworms.
No. 44. Suggestions for Judging the Agricultural Value and Adaptation of Land.
No. 45. The Chemical Analysis of Soils.
No. 46. Directions for sending Fruits for Identification.
No. 47. The Feeding Value of Apple Pomace.[1]
No. 48. Beet Residues for Farm Stock.[1]
No. 49. Cabbage, Cauliflower, Turnip, Rape, and Other Crucifers.[1]
No. 50. Rations for Dairy Stock.[1]
No. 51. Downy Mildew of Cucumbers.[1]
No. 52. The Control of Onion Smut.[1]
No. 53. Lime and Sulfur Solutions.[1]
No. 54. Poultry Manures, their Treatment and Use.[1]

Annual Reports.

Hatch Experiment Station: Tenth (1898) to seventeenth (1905), inclusive.

Massachusetts Agricultural Experiment Station: Twentieth (1908); Twenty-first, Part II. (1909); Twenty-second, Part I. (1910); Twenty-third, Part I. (1911); Twenty-fourth, Parts I. and II. (1912); Twenty-fifth, Part I. (1913); Twenty-sixth, Part I. and Complete (1913).

The general plan followed in the distribution of our publications has been the same as for several years. The total number of publications sent out to our different mailing lists was 81,735. In addition a very large number of publications was sent in answer to written requests. The extent of the demand is in part indicated by the number of requests — 1,411 — received during the two months, January and February, 1914. The total number of such requests during the year was rather over 5.000.

[1] Circulars Nos. 47 to 54 were not printed until after the end of the year covered by this report, but are here included as the date of printing the report is later than the dates of printing these circulars.

Mailing Lists.

The mailing lists which we maintain and the numbers in the several lists are shown in the following table: —

Residents of Massachusetts (general),	12,136
Residents of other States (general),	918
Residents of other States (general and technical),	1,082
Residents of foreign countries,	157
Newspapers,	525
Libraries,	383
Exchanges,	201
Cranberry growers,	1,728
Beekeepers,	4,450
Feed and fertilizer dealers and manufacturers,	645
Greenhouse vegetable growers,	1,848
Massachusetts florists,	1,100
Miscellaneous special lists,	589
United States Department of Agriculture, official list,[1]	2,275
Meteorological,	395
Total,	28,432

During the year there has been a total increase of rather over 1,800 addresses, — about 7 per cent. At the same time, however, there has been a decrease in the number on our general Massachusetts list. This is accounted for by the increase in special lists. The policy of specialization enables us to effect considerable economy in the circulation of our various publications, for reasons which must be apparent.

Needs of the Station.

In my last annual report particular attention was called to two needs which were discussed and urged at some length, — additional land for use in experiment and provision for experimental demonstrations in various parts of the State. Neither of these needs has been met, and in addition to referring once more to these which are even more urgent now, I must call at-

[1] Publications are not as a rule sent to all on this list, but only to presidents, directors libraries and specialists likely to be interested.

tention to another, — the provision of funds for work in the interest of our market gardeners.

The considerations which lead me to the conclusion that provision for all these needs should be made at as early a day as possible must of course be fully stated and supported before the committees of the Legislature. Some of the more important only, therefore, will be here stated, and that in the briefest possible form.

Additional Land. — New scientific discoveries are constantly broadening our horizon. Every research undertaken usually opens up new vistas and suggests new lines of inquiry. These cannot be undertaken within the limits of the area at present available for experimental use.

The attitude of the public toward the experiment station changes constantly in the direction of looking to it for information upon a constantly increasing number of questions, — questions which cannot be answered in the light of present knowledge and whose solution cannot be undertaken without additional land.

The poultry department of the experiment station finds itself confined to an area which renders satisfactory prosecution of inquiries already in progress quite impossible on account of the extreme difficulty — not to say impossibility — of maintaining a satisfactory degree of health and vigor in the stock without more land upon which the growing birds can range freely.

The considerations stated make it apparent that as the months and years have passed we must have felt and we do now most emphatically feel the need of more land; but not only has there been no increase in the area available for our work, there has been encroachment upon the limited area available made necessary by the growth of the institution. During the past year one line of experiments has been perforce entirely given up, while another has been much reduced in value by the loss of a portion of the plots involved. In each case this interference with our work has been made necessary by the location of new buildings.

In a few of the most urgent cases temporary provision for our needs has been made by leasing tracts of land. The station now leases five such tracts. This policy of leasing, as pointed out in my last report, is unsatisfactory: —

(*a*) Because it cannot be economically justified since the amount paid for the use of land in most cases is greater than would have been the interest at such rates as the State pays on the cost.

(*b*) On account of the fact that interruption of important lines of work because of termination of leases must in some cases be anticipated.

(*c*) Because the prices which must be paid for land suitably located tend constantly to increase. Purchase can be made now on more favorable terms than can be anticipated later.

The station is at present leasing more than thirty acres, and it is, by courtesy of the owners, using considerable additional land. If we look ahead no longer than I believe to be sound common sense I conclude that something like $40,000 should be made available in the near future for the purchase of land.

Experimental Demonstrations. — New crops and varieties of crops already cultivated among us need testing under varying local conditions as affecting soil and climate, both of which in this State vary widely. This work cannot possibly be done here. Further, conclusions based upon results of experiments here affecting the use of manures, fertilizers and lime, methods of cultivation, etc., need testing in different parts of the State, not only because of variations in soil and climate, but because of variations also in local economic conditions.

Provision should be made for work of this kind, for which purpose I estimate that $1,000 per year should be provided at as early a date as possible.

Work in the Interests of Market Gardeners. — As is well understood, the market-garden industry in this State is very prominent. It is one of the most important branches of our agriculture. The men engaged in the business have long urged that provision should be made for experimental work in their interest. Something can be done, and has been done, on the station grounds but the limitations of the area available restrict the possibilities; moreover, Amherst does not lie in a market-garden section; its soils are not typical of market-garden soils.

There appears to be a feeling among market gardeners, who point to the analogy of the action of the State in the interests of cranberry growers, that the State should make special provision for the establishment of a substation to be devoted to their interests. Numerous important reasons may be urged in favor of such action and doubtless it should ultimately be taken. I believe, however, that for the present the needs of the market gardeners can be fairly met if funds be appropriated for the employment of a suitable man who shall spend his time, during the period of active operations at least, on the market gardens in different parts of the State. Our market gardeners are among the most intelligent and progressive of our farmers. They understand the practical details of their business and apply to them a very high degree of intelligence. They do not particularly need assistance along these lines. The troubles which they experience and those in which they need the assistance of the experiment station are in my judgment for the most part connected with abnormal or disease conditions affecting their crops. They most need the assistance of a plant physiologist and mycologist, — a man able to diagnose plant diseases, to determine whether they are physiological or mycological in origin and who can advise on the proper course to be pursued. Such a man will undoubtedly in many cases discover diseases not yet fully understood.

If the policy of a substation be adopted it will be necessary to provide an expensive laboratory and equipment; for pathological, mycological and bacteriological work are impossible without. Such a laboratory and equipment we now have at the station in Amherst; and a suitable man working among the market gardeners would be able to collect and send material for investigation to this laboratory, where specialists already employed would be able to give it prompt attention.

This traveling expert would also be able to study and make records of the local conditions. He should of course be a good man — a man of considerable experience as well as careful training. A man, however, might be found thoroughly qualified for work of the kind under discussion at a lower salary than would be needed for a man fitted to carry on laboratory investigations. This policy of providing for a traveling expert who should spend his time among the market gardeners in the different parts of the State would, I believe, fairly meet the present need, and may be urged, to restate the principal considerations more briefly, for the following reasons: —

1. He would study conditions locally in the various parts of the State where his services seemed to be needed.

2. If such a man be employed the more purely scientific work connected with the investigation of diseases can be carried on at the station without material increase in the present equipment and by the experts now working at the station.

I would, therefore, strongly urge provision for the employment of a traveling expert, believing that with such an expert the immediate pressing needs of the market gardeners may be fairly met, thus rendering the much larger appropriation which would be essential for the establishment of a substation completely equipped for all lines of work for the present unnecessary. I estimate that for the employment of such a man as is suggested, and to meet the necessary traveling and other expenses, an appropriation of about $2,500 per year will be required.

Private Work.

The attitude of the experiment station relative to undertaking private work for individuals, especially chemical analysis, for which most of the requests for such work come, was fully stated in the twenty-sixth annual report. It seems necessary at this time, however, to once more emphasize the fact that the experiment station is organized and supported for work in the interest of the public. It is contrary to its general policy to undertake work for individuals which has no general or public interest. For the few exceptions the reader is referred to the twenty-sixth annual report.

I desire, however, once more to call particular attention to the fact that there is much misapprehension among owners and operators of land as to the probable value to them of a chemical analysis of their soils. Such analysis does not clearly indicate the crop adaptation nor the manurial or fertilizer needs. These are determined more largely by the structure and the consequent physical characteristics of the soil than by variations in the chemical composition. In spite of the frequency with which these facts have been pointed out the station still receives a very large number of samples of soil with requests for analysis. Those interested in learning what soils are suited for and their probable value are urged to write for a circular which discusses methods of determining these important points by examination on the spot, — methods which can easily be carried out by any intelligent and careful observer.

In all cases where a study of the conditions and the soil in accordance with the directions of the circular (No. 44) referred to leads to the conclusion that the soil is sour the station will determine the degree of acidity provided a sample taken in accordance with its directions is forwarded for the purpose.

CONTROL WORK.

There has been no change during the past year in any of the laws relative to the control work with which the station is charged. The following table shows the number of official samples taken in each of the years 1909 to 1914, inclusive: —

Number of Official Samples.

Year.	Fertilizers.		Feeds.	
	Brands.	Samples.	Brands.	Samples.
1909, ...	458	1,052	196	895
1910, ...	487	890	195	946
1911, ...	519	1,063	204	1,055
1912, ...	527	1,180	194	902
1913, ...	571	1,299	227	1,115
1914, ...	606	1,307	1,002	924

The shortage and consequent high price of potash salts due to the European war will undoubtedly reduce the number of brands of fertilizers offered in our markets, and will also, without doubt, lead to a reduction in the percentage of potash in many of these brands.

Attention is called to the fact that the station has no authority to require any definite percentage of any plant-food element.

The composition of every fertilizer is entirely at the discretion of the maker. The law requires simply that the dealer state and guarantee the composition.

LINES OF INVESTIGATION.

Most of the lines of investigation, both of the more general and of the more purely research character, referred to in recent reports are still continued. There have been minor modifications in a number of lines, made desirable by the progress of the inquiry. These changes have in some cases rendered desirable a restatement for the director of the office of experiment stations in the case of investigations coming under the Adams fund. No enumeration of the lines of investigation, either general or research, seems necessary at this time for reasons which the statements already made must make apparent.

THE ASPARAGUS SUBSTATION, CONCORD.

No changes requiring mention have occurred in the general management of the substation for investigations connected with asparagus. Mr. Prescott has efficiently looked after the details of cultivation and the determination of the yields under the varying fertilizer treatments, while Mr. Norton of the department of agriculture, as heretofore, has had charge of the breeding work.

There was very little rust in 1913 and the same is true of the year 1914. This fact, while somewhat unfavorable from the standpoint of Mr. Norton, whose object is the production of rust-resistant varieties, was decidedly favorable to obtaining a true measure of the effects and value of the different fertilizer combinations. The crop of 1914 was much the largest so far obtained, and on several of the best plots was at the rate of about 8,000 pounds per acre.

Plant-food Requirements.

The results obtained in 1914 are in very close agreement with those obtained in 1913; and as they were quite fully stated in the twenty-sixth annual report, it seems unnecessary to make a restatement at this time. A full discussion of the subject is reserved for a final presentation, which will include a full account of the plan of the experiments and of the results throughout the entire period.

THE CRANBERRY SUBSTATION, WAREHAM.

Bulletin No. 160, Part II., page 91, which is a part of this annual report, gives a full account of the experimental work with cranberries during the past year.

The crop produced upon the bog in 1914 was much smaller than in 1913, which should perhaps have been anticipated, since cranberries, like many varieties of apples, show a marked tendency towards much heavier bearing every alternate year.

The following tables will be of interest as they show separately the full expenditure in the commercial management of the cranberry bog and the expenditure immediately connected with the experimental work. Neither statement includes any allowance on account of the salary of Dr. Franklin, who is in local charge.

The tables show also the gross proceeds for the year, amounting to $2,529.36, as against $6,686.87 the previous year. Not only was the crop comparatively small last year, — prices were low as well, which accounts for an abnormally low return.

Bog Account.

Maintenance: —		
Tools or similar equipment bought or repaired,	$116 15	
Oil for engine, etc. (gasoline, kerosene and lubricating),	97 36	
Engine and bog pump repairs,	191 85	
Pumping labor,	97 50	
Bees, rental of,	6 00	
Mowing of upland,	57 25	
Weeding,	31 32	
Fertilizing,	4 22	
Digging out ditches,	61 36	
Repairs to buildings,	12 10	
Lumber and hardware,	59 59	
Raking of vines after picking,	71 63	
Amount carried forward		$806 33

Amount brought forward		$806 33
Maintenance — *Concluded.*		
Resanding bogs, ...	54 33	
General teaming, ...	15 37	
Sundries, ...	19 42	
Miscellaneous labor, ...	47 33	
		$942 78
Harvesting: —		
Picking, ...	$544 16	
Separating, ...	25 00	
Screening, ...	71 97	
Packing, ...	10 37	
Carting berries, ...	50 99	
Coopering, ...	14 91	
Packing materials, ...	67 20	
		784 60
Improvements: —		
Blowing out stumps (labor and dynamite), .	$93 47	
Building roads, ...	70 80	
Teaming, ...	10 42	
		174 69
Total, ...		$1,902 07

Experimental Account.

Experimental: —		
Labor, ...	$350 85	
Supplies and apparatus, ...	245 65	
Chemicals (including insecticides), ...	20 65	
		$617 15
Stationery and postage, ...		34 82
Traveling expenses, ...		136 65
Rental of dry bog, ...		100 00
Stenographer, ...		37 30
Contingent: —		
Freight, ...	$1 09	
Express, ...	19 82	
Surveying, ...	5 00	
Telephone, ...	28 16	
Furnishings, ...	4 00	
Incidentals, ...	70	
		58 77
Total, ...		$984 69

The total sales for the year were as follows: —

Fruit,	$2,511 86
Vines,	17 50
	$2,529 36

The experimental work of the year has followed the general lines mentioned in recent reports.

Weather observations in co-operation with the United States Weather Bureau have been continued, and as a consequence of the records made in connection with these observations and close study of the incidence of frost in different parts of the cranberry district Dr. Franklin feels increasing confidence in his ability to forecast frosts.

A preliminary trial of second-hand shade cloth (used one year by tobacco growers) for covering the vines for protection from frost indicates that this method will prove of value in the case of bogs without water for flooding.

The results obtained in the spraying experiments, carried out in co-operation with the United States Department of Agriculture under the immediate direction of Dr. Shear of the department, have given results somewhat at variance with those obtained in earlier years, and on the whole they do not clearly indicate such methods of spraying as have been tried to be distinctly beneficial. Dr. Franklin has noticed what seems to him a rather serious harmful influence upon the development of the roots of the vines to follow spraying.

As a result of Dr. Franklin's continued careful observations and experiments he has been able to advise in greater detail and with more confidence methods of management which will tend to prevent or greatly reduce the amount of insect damage to the vines and fruit.

Dr. Franklin has discovered that one of the Chalcidids is parasitic upon the eggs of the fruit worm, which is, everything considered, probably the most serious insect enemy of cranberry growers. There appears to be no doubt that this is the most important parasite of any injurious cranberry insect thus far discovered, and Dr. Franklin is now studying the question whether artificial methods of increasing the effectiveness of this parasite can be discovered.

The fertilizer experiments have been continued, and this year with distinctly favorable results following the application of the fertilizers, especially that of the nitrate of soda. The increases in yield appear to be due to an increase in the proportion of blossoms which set rather than to an increase in size of the berries. Storage tests indicate a slightly impaired keeping quality in the product from fertilized plots. Whether, however, this is connected with a greater percentage of decay or to a greater proportion of loss of water from the more succulent fruit has not been determined.

INVESTIGATION.

The department reports which follow present a general description of the principal experimental work in each, and to these reports reference should be made for detailed information.

Agricultural Department.

The agricultural department has published one bulletin, No. 162, "Phosphates in Massachusetts Agriculture." This will be found in Part II. of this report. The results presented in this bulletin indicate clearly that dissolved rather than natural rock phosphates should generally be employed in Massachusetts agriculture.

The experiments for comparison of different materials as sources of nitrogen used with and without lime indicate a very marked difference in relative effectiveness, especially of the sulfate of ammonia, which without lime does not increase such crops as clover, while with lime it compares favorably with any of the other nitrogen materials. With nitrate of soda, on the other hand, the growth of clover on the unlimed portion of the plots appears to be substantially as good as on the portion of the plots which has been heavily limed. These differences, as will be readily understood, are due in the case of the sulfate of ammonia to the residual acid left in the soil, and in the case of the nitrate of soda to the residual alkali, which renders the use of lime comparatively unnecessary.

The continued comparison of muriate and high-grade sulfate of potash used in connection with bone meal has shown the usual characteristic differences, resulting in a very marked superiority of yield of raspberries, blackberries and rhubarb on the sulfate and of asparagus on the muriate.

The experiments to determine the relative value of all the available potash salts and feldspar as sources of potash indicate a considerable superiority of the sulfate as compared with kainit, that feldspar seems to be absolutely unavailable, and that nitrate and carbonate are valuable sources of potash, the crop for the year being potatoes.

The comparison of different phosphates indicates: —

1. That the dissolved phosphates greatly promote rapid growth in the early stages of development, and that the different forms of bone meal are also fairly favorable to such growth; that slag meal is much superior to rock phosphates, the latter showing but little superiority to the no-phosphate plots.

2. The percentage of soft corn is affected, as might be anticipated from the statements just made, being highest on the no-phosphate plots, followed closely by the rock phosphates, and least on the dissolved phosphates.

3. Dissolved phosphates, the bone meals and slag give a larger average increase in crop than the rock phosphates.

In the soil tests, both north and south, the fact that potash is the dominant plant-food requirement for soy beans and clover is again shown.

The top-dressing experiments with permanent mowings have shown lower returns than usual, apparently because the weather conditions at the critical period have been highly unfavorable to clover, which was almost entirely absent during the past year from fields so top-dressed that it is usually abundant.

The Chemical Department.

The chemical department, besides publishing two bulletins in the control series, one on fertilizers, the other on feeds, has published two others: No. 158, discussing the nutritive value of certain feeds, and No. 161, "The Effect on a Crop of Clover of Liming the Soil and Toxic Effect of Iron and Aluminum Salts on Clover Seedlings."

The results presented in Bulletin No. 158 indicate among other things that molassine meal possesses about three-fourths the feeding value of corn meal; that it does not increase, but rather tends to decrease digestibility of coarse feeds fed in connection with it. It, however, seems to serve as an appetizer and in some cases increases palatability of coarse feeds, and is recommended for horses, as it seems to render attacks of colic less probable.

The bulletin shows that the quality of cottonseed meal and hulls seems to grow poorer from year to year. The percentage of hulls shows a tendency to increase and the more abundant these are the lower the feeding value. The results presented indicate that cottonseed feed meal possesses only about one-half the feeding value of good cottonseed meal, while it sells at about three-fourths of the price of the latter.

Cocoa shells are believed to possess about one-half the feeding value of corn meal.

Wheat or grain screenings, if finely ground, may constitute a useful feed, and the better samples have approximately the feeding value of wheat bran. Such feeds exhibit wide variations.

Flax shives are not believed to be worth the attention of eastern feeders.

Mellen's food refuse will, it is believed, prove desirable if it can be purchased at about three-fourths the cost of wheat bran.

The results presented indicate that CXX feed is a quite inferior product.

Professor Morse shows in Bulletin No. 161 a great increase in the size of clover plants and in the percentage of nitrogen in them, both on the no-nitrogen plots and on plots supplied with nitrogen in the form of sulfate of ammonia, following a heavy application of lime. To a lesser degree similar differences are shown where other nitrogen materials are applied. These differences, in the opinion of Professor Morse, are produced rather by the action of the lime on the properties of the soil than by its action within the plant itself.

Mr. Ruprecht shows that aluminum sulfate in culture solutions has a very toxic action on clover seedlings if present in quantity greater than forty parts per million, and that ferrous sulfate if present in concentration above four parts per million exerts a somewhat similar effect. He shows further that this toxic effect can be overcome in large measure in dilute solution by the use of calcium carbonate.

His experiments appear to indicate that one of the principal reasons for the failure of clover on plots fertilized with sulfate of ammonia without lime is due to the fact that aluminum and iron are to some extent brought into solution by the action of the sulfuric acid of the ammonium sulfate.

The report of the chemist calls attention to a number of improvements in chemical methods, especially in methods connected with the examination of fats, which have been perfected by Mr. Holland and Mr. Buckley. It makes brief reference to the investigations of Professor Morse on the chemical composition of asparagus, and briefly presents the principal results of some investigations in animal nutrition.

It has been shown that vegetable ivory, in spite of its hard and horny nature, appears to be to a considerable extent digestible, and may be a food product of some value.

The report gives the usual account of the results of the inspections of commercial fertilizers and food stuffs and the examination of Babcock glassware.

The Botanical Department.

The botanical department has published one bulletin during the year, No. 156, "Electrical Injuries to Trees." This bulletin gives important information on the following points: the electrical resistance in trees; the effects of alternating and of direct currents; the effects of lightning and earth discharges; and discusses methods of preventing injury from contact with wires carrying electric currents.

The report of the botanist calls attention to some of the plant diseases which have been unusually common during the past year. Among these the Rhizoctonia disease of potatoes is one of the most serious.

The report points out that chestnut blight is spreading, but expresses the opinion that the disease is held somewhat in check by natural causes, probably climatic.

Attention is called to a number of diseases, new (so far as known) in this State, the seriousness of which is not at present understood.

The Entomological Department.

The entomological department has published one bulletin during the year, No. 157, "The Marguerite Fly." This bulletin gives an account of the life history and habits of this highly injurious insect, and discusses methods of control of this serious greenhouse pest. The author recommends spraying with nicotine solutions. "Black Leaf 40," diluted with 400 to 450 parts of water applied at intervals of about twelve days (or oftener if the temperature of the greenhouse is unusually high) has proved effective with Marguerites.

The Horticultural Department.

The horticultural department has published one bulletin during the year, No. 159, "The Technical Description of Apples." This bulletin calls attention to variety characters which the writer believes will prove of much value in determining varieties in the absence of specimens of fruit. The methods of determination proposed are based in considerable measure upon leaf characters, and the bulletin should prove a valuable contribution to this important subject.

The report of the horticulturist, especially that part of it contributed by Dr. Shaw, calls attention to the progress of investigations on the effect of the stock on the scion. Unanticipated difficulties have been experienced in getting certain varieties established upon their own roots, but such a degree of progress is recorded as will make possible the planting of a considerable proportion of the area available with trees on known roots the coming spring.

The Veterinary Department.

The investigational work of the veterinary department has been directed chiefly toward the development of methods for the diagnosis of bacillary white diarrhœa in adult fowls and the prevention of hog cholera by the use of anti-hog cholera serum.

During the past year the method recommended in Bulletin No. 148 has been put to practical test. It has been found possible to detect individuals harboring *Bacterium pullorum,* thus making possible the elimination of such individuals from breeding flocks. Of one thousand chickens hatched from eggs from tested hens in one flock not one died of white diarrhœa, while during the previous season, before the bearers of infection had been eliminated from the flock, only two hundred chicks of two thousand hatched survived the ravages of the disease.

The reports of the treasurer and of the different departments immediately follow the director's report. The bulletins to which reference has been made will be found in Part II. of the annual report.

WM. P. BROOKS,
Director.

REPORT OF THE TREASURER.

ANNUAL REPORT

Of Fred C. Kenney, Treasurer of the Massachusetts Agricultural Experiment Station of the Massachusetts Agricultural College, for the Year ending June 30, 1914.

United States Appropriations, 1913–14.

	Hatch Fund.	Adams Fund.
Dr.		
To receipts from Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1914, under acts of Congress approved March 2, 1887 (Hatch fund), and March 16, 1906 (Adams fund),	$15,000 00	$15,000 00
Cr.		
By salaries,	$12,099 49	$13,047 20
labor,	1,280 80	901 01
publications,	704 34	–
postage and stationery,	13 33	26 38
freight and express,	–	13 26
heat, light, water and power,	8 63	–
chemicals and laboratory supplies,	39 78	132 57
seeds, plants and sundry supplies,	119 72	292 55
fertilizers,	675 16	241 12
feeding stuffs,	–	–
library,	30 92	22 57
tools, machinery and appliances,	20 43	–
furniture and fixtures,	–	29 04
scientific apparatus and specimens,	–	153 87
live stock,	7 40	–
traveling expenses,	–	70 44
contingent expenses,	–	–
buildings and land,	–	69 99
Total,	$15,000 00	$15,000 00

State Appropriations, 1913–14.

Cash balance brought forward from last fiscal year,	$11,574 55
Cash received from State Treasurer,	23,500 00
fertilizer fees,	11,244 00
farm products,	9,061 91
miscellaneous sources,	9,631 40
	$65,011 86

Cash paid for salaries,	$19,965 04
labor,	13,944 65
publications,	1,999 82
postage and stationery,	1,380 09
freight and express,	544 29
heat, light, water and power,	375 93
chemicals and laboratory supplies,	1,307 46
seeds, plants and sundry supplies,	1,536 36
fertilizers,	201 40
feeding stuffs,	1,690 22
library,	507 27
tools, machinery and appliances,	538 96
furniture and fixtures,	880 97
scientific apparatus and specimens,	931 45
live stock,	80 10
traveling expenses,	3,326 12
contingent expenses,	802 67
buildings and land,	1,105 68
miscellaneous,	96 30
balance,	13,797 08
Total,	$65,011 86

REPORT OF THE ASSISTANT AGRICULTURIST.

E. F. GASKILL.

The experimental work in the agricultural department during the past year has followed the same general lines of investigation as in previous years. Most of the experiments in this department have dealt with some phases of the question of soil fertility. Such work to be of value must be conducted over a long period of years; and some of the fertilizer experiments started by the late Dr. Goessmann are continued with minor modifications. The work this year has involved the use of 189 plots, 13 orchard plots, 4 pasture plots and 147 closed plots. The latter are used to check results obtained in the field.

The results obtained from year to year have been published in annual reports of the station, but it is hoped in the near future to bring all of this information for each experiment together in bulletin form.

It has not been the custom to report the work in detail each year, therefore only a few of what seem to be the more striking results will be presented.

Field A, or the Nitrogen Experiment.

This experiment was begun in 1890 and is a study of the relative value as sources of nitrogen of barnyard manure, nitrate of soda, sulfate of ammonia and dried blood.

In 1913 the west half of each plot received an application of hydrated lime at the rate of 2 tons per acre.

This year the field was seeded on May 16 with a mixture of timothy, red-top and clover. Oats (1 bushel per acre) were sown as a nurse crop. The oats were cut July 23 and made into hay. The average yield for this year on the different nitrogen and no-nitrogen plots is shown in the following table: —

Average Yields per Acre, 1914 (Oat Hay).

Plots.	Limed (Pounds).	Unlimed (Pounds).	Average (Pounds).
Nitrate of soda, 1 and 2,	4,350	2,700	3,525
Dried blood, 3 and 10,	3,550	2,500	3,025
Sulfate of ammonia, 5, 6 and 8,	3,533	2,167	2,850
No nitrogen, 4, 7 and 9,	2,533	1,433	1,983
Manure, 0,	3,200	2,100	2,650

These figures show that the application of lime increased the yield on each plot.

On the basis of 100 for nitrate of soda, the relative standing of the different nitrogen plots and no-nitrogen plots, as measured by total yield during the past season, was as follows: —

	Oat Hay (Per Cent.).
Nitrate of soda,	100.00
Dried blood,	85.81
Sulfate of ammonia,	80.85
Manure,	75.18
No nitrogen,	56.25

The relative standing of the different materials as indicated by total yield for the twenty-five years during which the experiment has continued is as follows: —

	Per Cent.
Nitrate of soda,	100.00
Manure,	93.53
Dried blood,	93.21
Sulfate of ammonia,	88.38
No nitrogen,	72.35

On the basis of increase as compared with the no-nitrogen plots the relative standing for the different fertilizers for the twenty-five years is as follows: —

	Per Cent.
Nitrate of soda,	100.00
Manure,	76.60
Dried blood,	75.44
Sulfate of ammonia,	57.97

Considering the relative standing of the different nitrogen fertilizers on the basis of yields per acre, nitrate of soda, as in previous years, stands first.

On the basis of increase as compared with the no-nitrogen plots for the entire period of the experiment (twenty-five years) the nitrate of soda also ranks first.

The crop of grass and clover was not cut, but on September 9 the following condition was noted: on the limed area of each plot there was a very luxuriant growth, — practically all clover. There was no apparent difference in the amount of clover on the nitrogen and no-nitrogen plots.

On the unlimed area of all plots, except those receiving nitrate of soda, the stand of clover was much inferior to that on the limed area. The stand of clover on the unlimed area of the plots receiving sulfate of ammonia was much inferior to that on the unlimed areas of any of the other plots. The stand of clover on the limed area of the sulfate of ammonia plots was about as good as that on the limed area of the nitrate of soda and no-nitrogen plots. The unlimed area of the nitrate of soda plots seemed to produce practically as good a stand of clover as the limed areas.

Comparison of Muriate and High-grade Sulfate of Potash (Field B).

The work on this field, where for so many years we have had under comparison the two potash salts, muriate and high-grade sulfate, has been continued. The following table shows the increased yields per acre due to the use of the two potash salts: —

Crop.	Increase due to Use of —		Cash Value of Increase.	Increased Cost of Sulfate.	Increase returns from —	
	Sulfate (Pounds).	Muriate (Pounds).			Sulfate.	Muriate.
Raspberries,	1,635	–	$196 20	$1 05	$195 15	–
Blackberries,	537	–	34 40	1 05	33 35	–
Rhubarb,	4,538	–	90 76	1 05	89 71	–
Asparagus,	–	180	18 00	1 05	–	$19 05

In case of the raspberries the sulfate plot produced at the rate of 1,635 pounds per acre more than the muriate. Considering the raspberries worth 15 cents per quart it is seen that the sulfate returned $196.20 more per acre than the muriate. The two salts are applied on the basis of equal applications of actual potash, which means about 200 pounds per acre of each. Used at these rates the sulfate cost this year about $1.05 more per acre than the muriate.

The sulfate plot also ranks ahead of the muriate plot for the crops of blackberries and rhubarb. The muriate plot, however, ranks ahead in case of the asparagus, having a balance in its favor of $19.05 per acre.

Comparison of Potash Salts (Field G).

In this experiment we have had under comparison for seventeen years seven different materials that may be used as sources of potash. There are 5 check or no-potash plots, and each material furnishing potash is used on 5 different plots, thus making 40 plots in the field. The crop this year was potatoes. The following table gives the average yields per acre on the different potash salts, also the relative standing of each: —

Fertilizer.	Large (Bushels).	Small (Bushels).	Total (Bushels).	Rank, No potash equals 100.
No potash,	122.80	22.80	145.60	100.00
Kainit,	129.40	15.23	144.63	99.33
High-grade sulfate of potash,	173.53	15.97	189.50	130.15
Low-grade sulfate of potash,	159.70	15.90	175.60	120.60
Muriate of potash,	177.40	12.63	190.03	130.52
Nitrate of potash,	190.83	15.20	206.03	141.50
Carbonate of potash,	193.33	20.10	213.43	146.59
Feldspar,	124.13	13.57	137.70	94.57

The small yields obtained are due largely to the fact that the soil is badly infested with the potato scab fungus.

Potatoes were grown this year for the purpose of studying, in co-operation with the department of vegetable pathology, the control of this fungus. The experiment will be repeated another year.

Comparison of Different Phosphates.

On one of our fields we have had under comparison since 1897 ten different materials that are used as sources of phosphoric acid. Each plot has received annually a liberal application of nitrogen and potash in highly available forms. The different phosphates are used in such quantities as to supply equal phosphoric acid to each plot. There are 3 check plots which receive no phosphates.

This year a very good crop of rye was plowed under in May. The field received an application of hydrated lime at the rate of 1 ton per acre.

The crop this year was Longfellow corn, planted May 28 and cut and stooked September 26, on which date it was fairly well matured. The following table shows the average height of the plants on the different plots on July 10: —

Plot.	Fertilizer.	Inches.	Plot.	Fertilizer.	Inches.
1, . .	No phosphate, .	32.23	8, . .	Dissolved boneblack,	42.15
2, . .	Arkansas rock, .	28.92	9, . .	Raw bone, . .	40.02
3, . .	South Carolina rock,	30.83	10, . .	Dissolved bone meal,	38.79
4, . .	Florida soft rock, .	32.62	11, . .	Steamed bone, . .	40.20
5, . .	Slag, . . .	35.67	12, . .	Acid phosphate, .	42.05
6, . .	Tennessee rock, .	32.99	13, . .	No phosphate, .	29.69
7, . .	No phosphate, .	30.96			

The above figures make it very apparent which phosphates are the more quickly available.

The following table shows the yield per acre on the different plots: —

Plot.	Fertilizer.	Hard Corn.	Soft Corn.	Stover (Pounds).	Increase over No Phosphate.	
					Hard Corn.	Stover (Pounds).
1,	No phosphate,	74.6	5.0	6,720	-	-
2,	Arkansas rock,	67.6	7.2	7,120	6.3	1,240
3,	South Carolina rock,	75.5	5.0	6,880	14.2	1,000
4,	Florida soft rock,	68.2	7.4	6,920	6.9	1,040
5,	Slag,	70.8	6.0	8,640	9.5	2,760
6,	Tennessee rock,	72.0	6.0	6,640	10.7	760
7,	No phosphate,	66.4	8.4	6,560	-	-
8,	Dissolved boneblack,	80.8	3.4	7,240	19.5	1,360
9,	Raw bone,	82.8	2.8	7,400	21.0	1,520
10,	Dissolved bone meal,	74.5	2.8	7,280	13.2	1,400
11,	Steamed bone,	75.9	4.6	6,920	14.6	1,040
12,	Acid phosphate,	71.8	2.8	6,240	10.5	360
13,	No phosphate,	42.8	9.1	4,360	-	-

Plot.	Fertilizer.	Per Cent. of Hard and Soft Corn.	
		Hard.	Soft.
1,	No phosphate,	93.7	6.3
2,	Arkansas rock,	90.4	9.6
3,	South Carolina rock,	93.8	6.2
4,	Florida soft rock,	90.2	9.8
5,	Slag,	92.2	7.8
6,	Tennessee rock,	92.3	7.7
7,	No phosphate,	88.8	11.2
8,	Dissolved boneblack,	96.0	4.0
9,	Raw bone,	96.7	3.3
10,	Dissolved bone meal,	96.4	3.6
11,	Steamed bone,	94.3	5.7
12,	Acid phosphate,	96.2	3.8
13,	No phosphate,	82.5	17.5

North Corn Acre.

In this experiment we have had under comparison for twenty-five years two fertilizer mixtures, in one of which the percentage of potash is high and that of phosphoric acid low; while in the other (which represents about the average analysis of the commercial corn fertilizers offered on our markets) the percentage of phosphoric acid is high and that of potash low. For the past nineteen years the rotation has been two years grass and two years corn. This year the field was in grass, and the combination containing the higher percentage of potash gave more hay than the mixture containing the lower percentage of potash. This result is similar to results obtained in previous years, except that owing to the severe drought of the last season we did not harvest a rowen crop.

North Soil Test.

In this experiment there are 13 plots which have received the same fertilizer treatment for twenty-six years. The west half of each plot has received three applications of lime. In 1899 and 1904 lime was applied at the rate of 1 ton per acre and in 1907 at the rate of ½ ton per acre. This year the crop was mixed grass and clover. The following table gives the yields per acre on the different plots: —

Yield per Acre (Pounds).

Plot.	Fertilizer.	Limed.		Unlimed.	
		Hay.	Rowen.	Hay.	Rowen.
1, 4, 8 and 12,[1]	No fertilizer,	2,242½	220	1,065	–
2,	Nitrate of soda,	2,870	–	2,020	–
3,	Dissolved boneblack,	1,680	–	1,490	–
5,	Muriate of potash,	4,140	1,400	1,280	–
6,	Nitrate of soda, Dissolved boneblack,	3,800	40	2,540	–
7,	Nitrate of soda, Muriate of potash,	3,080	1,000	2,000	–
9,	Dissolved boneblack, Muriate of potash,	3,620	800	1,030	–
10,	Nitrate of soda, Dissolved boneblack, Muriate of potash,	5,310	800	2,600	–
11,	Plaster,	2,400	200	860	–
13,	Nitrate of soda, Dried blood, Dissolved boneblack, Muriate of potash,	7,240	1,000	3,000	–

[1] Average.

The rowen crop was unusually light, owing to the deficiency in rainfall. On all of the unlimed plots and on 2 of the limed plots the crop was too small to cut. The rowen crop was practically all clover, and the figures in the table show quite conclusively the necessity of using potash and lime for a leguminous crop.

The continued use of these different materials greatly affects the character of the growth. We find practically no clover on the unlimed halves of the no-fertilizer plots, nor on the unlimed portions of the plots receiving nitrate of soda, dissolved boneblack, nitrate of soda and dissolved boneblack, or plaster, while on all plots where potash is used we find clover, but not as abundantly as on the limed halves of the same plots.

South Soil Test.

On this field each plot has received the same fertilizer treatment for twenty-six years. The crop this year was medium green soy beans, which were injured by an early frost, before the beans matured. The crop was cut soon after the frost, before many of the leaves had fallen off, and made into hay. Following are the yields per acre from some of the plots: —

Plot.	Fertilizer.	Soy Bean Hay (Pounds).
3, 6, and 12,	Nothing,	1,500[1]
1,	Nitrate of soda,	3,500
2,	Dissolved boneblack,	900
4,	Muriate of potash,	6,000
10,	Nitrate of soda, Muriate of potash,	9,100
11,	Dissolved boneblack, Muriate of potash,	7,700
14,	Nitrate of soda, Dissolved boneblack, Muriate of potash,	9,800
5,	Lime,	1,200
13,	Plaster,	1,700
7,	Manure,	11,500

[1] Average of 3 plots.

These results are in accordance with those obtained in previous experiments. The largest crop is obtained on plots where potash is used alone or in combination with other materials.

Grass Plots.

The experiment in top-dressing grass lands with different materials used in rotation has been continued. The yield of hay this year was below the average. The following table gives the yields per acre: —

Plot.	Fertilizer.	Hay (Pounds).	Rowen (Pounds).
1,	Manure,	3,571	1,670
2,	Bone meal, Muriate of potash,	3,698	1,359
3,	Muriate of potash,[1] Basic slag,[1]	3,480	1,405

The average yield to date under the three systems of top-dressing are: —

	Pounds per Acre.
When top-dressed with manure,	6,021
When top-dressed with bone meal and potash,	5,914
When top-dressed with slag and potash,[2]	5,542

The fescue mixture produced this year when top-dressed with manure 331 pounds more of hay per acre than the timothy mixture, and 270 pounds more rowen.

On the plot top-dressed with bone meal and muriate of potash the difference in favor of the fescue mixture was 1,008 pounds hay per acre and 263 pounds rowen.

The results obtained are similar to those obtained for the last few years. During the first few years of the experiment the timothy mixture produced the larger yields, but for the past three or four years the fescue mixture has produced the larger crop.

[1] In place of ashes used in earlier years. [2] Formerly wood ashes.

Sulfate of Ammonia v. Nitrate of Soda as a Top-dressing for Permanent Mowings.

This field has been continuously in grass since 1899. In 1908 the present plots were laid off, with an idea of studying the relative value of sulfate of ammonia and nitrate of soda as a top-dressing for grass. The materials are used in such quantities as to supply equal nitrogen to each plot. There is a check plot which receives an application of: —

	Pounds per Acre.
Bone meal,	400
Muriate of potash,	180
Basic slag,	400

The sulfate of ammonia and the nitrate plots also receive this mixture. The sulfate of ammonia has been used at the rate of about 175 pounds per acre, and the nitrate of soda at about 233⅓ pounds per acre. The following table shows the increased yield per acre due to the use of the two chemicals for each year since the experiment started: —

Year.	Sulfate of Ammonia.		Nitrate of Soda.	
	Hay (Pounds).	Rowen (Pounds).	Hay (Pounds).	Rowen (Pounds).
1908,	1,030.0	505.0	1,465.0	545.0
1909,	1,892.0	-	1,805.0	-
1910,	870.0	—485.0	1,455.0	—690.0
1911,	1,012.5	—66.5	1,262.5	—60.5
1912,	1,604.0	162.0	1,134.0	130.5
1913,	1,402.5	36.5	1,122.5	18.0
1914,	975.0	86.0	1,133.5	335.5
Averages,	1,255.0	39.7	1,339.6	46.4

From the above table it will be apparent that the nitrate of soda has this year produced the greater increase. This is true in four out of the seven years, and the net excess of the nitrate plot over the sulfate plot for the seven years is 592 pounds per acre.

In case of the rowen there are two years in which neither the sulfate nor the nitrate produced as large a crop as the check plot. For the entire period of the experiment the increase on the nitrate plot is slightly better than that on the sulfate plot.

The following table shows the increase in cost per acre due to the addition of sulfate of ammonia and nitrate of soda to the mixture: —

Year.	Cost per Acre.	
	Sulfate of Ammonia.	Nitrate of Soda.
1908,	6.73	6.66
1909,	6.34	6.02
1910,	6.22	5.73
1911,	6.10	5.68
1912,	6.23	5.92
1913,	6.42	6.62
1914,	6.68	6.29
Averages,	6.39	6.13

From the tables it will be seen that nitrate of soda has produced the larger increase and at a lower cost.

Lime Experiment.

An experiment to study the relative value of different sources of lime on the basis of equal applications of combined calcium and magnesium oxides was begun this year. The field selected for this experiment is the one on which for so many years we studied the effects of spring and winter applications of manure. The plots have not received any manure since 1911.

There were five pairs of plots in the manure experiment, and since there are four different kinds of lime to be tested, one pair of plots is given up to each kind of lime and one pair is used as a check plot, receiving no lime. No manure or fertilizer of any kind was applied this year.

The crop grown was medium green soy beans, which were cut green and put in the silo with corn. The following table gives the yields per acre of hay in 1913 before liming, and of soy beans (cut green) in 1914 after liming. The second column shows the relative yield on the different plots, that on the no-limed plot being taken as 100: —

Actual and Relative Yields.

Fertilizer.	Before Liming, 1913.		After Liming, 1914.	
	Hay per Acre (Pounds).	No Lime equals 100.	Soy Beans[1] per Acre (Pounds).	No Lime equals 100.
Tobey lime,	5,284	141.7	13,692	148.0
Marl,	5,010	134.0	13,738	148.5
Ground limestone,	4,490	120.0	9,887	106.9
No lime,	3,730	100.0	9,250	100.0
Limoid,	5,100	136.7	10,437	112.8

[1] Cut green.

Attention is called to the fact that this is the first year of the experiment, and results above do not necessarily represent ultimate relative values.

Variety Test Potatoes.

The work of testing different varieties of potatoes has been continued. The seed planted this year was selected from the more promising varieties grown last year. This seed originally came from several different sources; the present season is the third year that the varieties have been grown on our plots.

The plan included two rows of each variety, every seventh row being a check variety. The Green Mountain was planted in the check rows. The following table gives the yield per acre of the five leading varieties: —

Late, 1912.	Bushels.	Early, 1912.	Bushels.
Sutton's Early Monarch,	312	Early Six Weeks,	155
Sir Walter Raleigh,	270	Trust Buster,	116
Clyde,	210	Buckbees Extra Early Rockford,	113
Quick Crop,	198	Early Surprise,	105
Snow,	189	Six Weeks,	102
Green Mountain (average of seven rows).	181		

Late, 1913.	Bushels.	Early, 1913.	Bushels.
Quick Crop,	155	Irish Cobbler,	114
Northern Star,	137	Petoskey,	110
Farmer Potato,	134	Early Surprise,	107
Sir Walter Raleigh,	128	Trust Buster,	104
Clyde,	126	Early Six Weeks,	89
Green Mountain (average of seven rows).	118		

Late, 1914.	Bushels.	Early, 1914.	Bushels.
Farmer Potato,	434	Early Six Weeks,	224
Sir Walter Raleigh,	422	Irish Cobbler,	208
Sutton's Early Monarch,	390	Early Surprise,	206
Quick Crop,	364	Trust Buster,	200
Clyde,	355	Johnson's Flour Ball,	189
Green Mountain (average of seven rows).	334		

In 1913 there was one check row that yielded better than any of the varieties. In 1914 one check row yielded practically the same as the Clyde.

REPORT OF THE CHEMIST.

JOSEPH B. LINDSEY.

1. Work of Investigation.

Mr. Holland and Mr. Buckley have continued their studies on the chemistry of butter fat. A method has been perfected for determining monohydroxy acids and dihydroxy acids and their glycerides. This method was published in detail in Bulletin No. 151 of the station.

A modification of the Hehner and Mitchell method has been made for determining the amount of stearic acid in the insoluble acids of butter fat. The stearic acid is determined by crystallization from a supersaturated solution of alcohol and stearic acid at approximately 0° C. It involves the use of a jacketed tank of ice and water with stirring apparatus, supersedes the earlier method in which alcohol and stearic acid were used without agitation, and yields a much larger amount of stearic acid in case of butter.

A method has been practically completed for the determination of unsaponifiable matter of oils and fats by continuous extraction of the saponified product after drying.

The fifth year of the stability test with olive oil is approaching completion and the results will be brought together for publication within a short time.

The new method for stearic acid is bound to prove very helpful in enabling us to determine, with a greater degree of accuracy, the chemical composition of the insoluble acids of butter fat.

Mr. Morse and Mr. Ruprecht have continued their work in investigating the chemistry of asparagus and the effect of fertilizers in modifying the character of the asparagus plant. The actual fertilizer effect on proportionate composition has been found to be slight, being most marked in case of the nitrogen and potassium contents.

The character of the sugar group is being studied by comparing the specific rotatory power of purified syrups obtained from different parts of the plant at different seasons. The change in rotation indicates a marked change in the character of the sugar groups at different stages of translocation and photosynthesis.

A study of the bog water from the so-called cranberry tiles has been continued. Samples of fruit and vines from groups of fertilized and unfertilized bogs have been preserved for analysis.

Considerable time has been devoted to the study of the effect of sulfate of ammonia in modifying the character of the soil and checking the normal growth of clover.

Drainage waters from sulfate of ammonia plots of Field A have been analyzed and point to the exhaustion of calcium as a base, but do not show any accumulation of sulfuric acid as a free acid. Another application of lime has been made to this field and has shown a very favorable effect on the growth of clover. This investigation is being continued. The problem is a complex one and involves a large amount of work before it can be hoped to secure definite results.

Dr. Lindsey has continued studies in animal nutrition. A large number of digestion experiments with sheep have been made during the year, upon such materials as Molassine Meal, vegetable ivory, pumpkins, carrots and cabbages.

A study of the digestibility of crude fiber in different cattle feeds has been undertaken but no decisive results have as yet been secured.

Two experiments have been completed to study the value of alfalfa as a roughage. It seems probable that a combination of hay, alfalfa and corn stover, together with corn-and-cob meal and a little cottonseed meal, will form a most satisfactory ration for dairy animals. The experiments indicate that it will hardly be advisable to have the coarse part of the ration consist entirely of alfalfa or even of alfalfa and corn stover.

A special study has been made of the nutritive value of vegetable ivory for dairy animals. The results thus far indicate that in spite of its hard, horny nature, animals are able to utilize this material as a source of nutrition. The material is being further investigated.

The value of New Mineral and Stone Meal fertilizers has been studied and is referred to under a separate heading.

The same remark may be made relative to the availability of organic nitrogen in commercial fertilizers, and of the relative value of basic phosphatic slag as a source of phosphoric acid.

2. Work of the Fertilizer Section.

The principal work of the fertilizer section, in charge of Mr. Haskins with Messrs. Walker, Jones and Frost as assistants, has been the annual inspection of commercial fertilizers. The number of brands registered, collected and analyzed during 1914 is considerably in excess of that in any previous year.

(*a*) *Fertilizers registered.*

During the season of 1914, 110 manufacturers, importers and dealers, including the various branches of the large corporations, have secured certificates for the sale of 564 different brands of fertilizer, agricultural chemicals, raw products and agricultural lime. They may be classed as follows: —

Complete fertilizers,	366
Fertilizers furnishing phosphoric acid and potash,	11
Ground bone, tankage and dry ground fish,	56
Chemicals and organic nitrogen compounds,	98
Agricultural limes,	33
	564

(*b*) *Fertilizers collected and analyzed.*

During 1914, 135 towns were visited, and 1,307 samples, representing 606 distinct brands, which include private mixtures, were drawn from stock found in the possession of 365 different agents and consumers. This represents 8 more samples and 35 more brands than were taken during the previous year.

Seven hundred and eighty-one analyses (603 distinct brands) have been made during the year's inspection. They are as follows: —

Complete fertilizers,	453
Fertilizers furnishing phosphoric acid and potash,	18
Ground bone, tankage and dry ground fish,	79
Nitrogen compounds,	105
Potash compounds,	43
Phosphoric acid compounds,	40
Lime compounds,	43
	781

Full details regarding the fertilizer inspection work will be found in Bulletin No. 2, control series, published in December, 1914.

(*c*) *Other Activities of the Fertilizer Section.*

Up to Dec. 1, 1914, analyses were made as follows: weights and dry matter determinations on 96 samples of millet for the agricultural department; dry matter determinations in connection with the basic slag and stone meal experiment on 13 samples of oats and 8 samples of potatoes; 45 dry matter determinations on corn, cob and stover in this experiment.

In connection with pot experiments to determine the relative nitrogen availability on some suspected samples of commercial fertilizer found in the 1913 fertilizer inspection, 114 dry matter and nitrogen determinations were made. This included weighing the product from each pot. In connection with another series of pot experiments with millet to determine the relative nitrogen availability on samples of fertilizer submitted by the Referee on Nitrogen for the Association of Official Agricultural Chemists, 42 dry matter and nitrogen determinations were made. This work was undertaken in order to compare the actual nitrogen activity of the water insoluble portion of these different nitrogen sources with the laboratory methods (the alkaline and neutral permanganate).

In addition to the above, 408 different substances have been received and analyzed for farmers, farmers' organizations and the various departments of the experiment station, as follows: —

Fertilizers and by-products used as fertilizers,	226
Lime products,	30
Soils for lime requirement test,	100

Soils for complete analysis,	4
Soils for partial analysis,	21
Tobacco soils suffering from over-fertilization, suspected of causing malnutrition of the crop,	14
Greenhouse soils suffering from over-fertilization, suspected of causing malnutrition of the crop,	13

The usual time has been given to co-operative work with the Association of Official Agricultural Chemists, Mr. Walker having served the association in the capacity of associate referee on phosphoric acid and Mr. Haskins as associate referee on nitrogen. In this connection studies have been made on new methods for the determination of the three fertilizer constituents (nitrogen, phosphoric acid and potash) in fertilizers.

(*d*) *Field Experiments with Basic Slag Phosphate.*

The work begun in 1913 to study the availability of the phosphoric acid in basic slag phosphate, as outlined by the Association of Official Agricultural Chemists, has been continued. The data resulting from this experiment would indicate that the field is not sufficiently depleted in phosphorus to warrant making the final field experiment, and it is probable that the growing of crops on the land another year will be necessary.

(*e*) *Field Experiments with New Mineral Fertilizer and Stone Meal.*

This experiment, begun in 1912, has been continued. The conclusions drawn from this year's experiment will be found in Bulletin No. 2, control series, published in connection with the results of the fertilizer inspection.

(*f*) *Other Vegetation Experiments.*

The experiment begun in the greenhouse in the winter of 1914 for the purpose of comparing the nitrogen availability of some suspected brands of fertilizer found in the 1913 fertilizer inspection was completed. Conclusions will be found in Fertilizer Bulletin No. 2, Control Series. Similar work has been started with fertilizers collected in 1914.

3. Report of the Feed and Dairy Section.

(*a*) *The Feeding Stuffs Law (Acts and Resolves for 1912, Chapter 527).*

During the past year Mr. Smith and Mr. Beals have examined 924 samples of feeding stuffs. In accordance with the feeding stuffs law, 1,002 brands of feeding stuffs were registered; some of those registered, however, were not offered for sale, or, if offered, were sold to such a limited extent that they were not found by the inspector.

The spirit of co-operation between dealer and those having in charge the enforcement of the feeding stuffs law has been, on the whole, very satisfactory, and only three cases have been brought for prosecution. The officials having the law in charge are always reluctant to bring cases into court except as a last resort or where the interests of the consumer are at stake, preferring to depend upon publicity and persuasion, if possible.

The importation from foreign countries of feeding stuffs has been increasing for several years. Thus far the amount imported has not affected the local market, the imported feeding stuffs having sold at ruling prices, or, in some cases, for prices in excess of those charged for domestic products. Recently cargoes of corn and wheat feeds have been received from the Argentine Republic, a cargo of dried beet pulp has been brought to Boston from Spain, Canadian wheat feeds have been coming in for some time, and Molassine meal and the Bibby feeds, both English products, are quite extensively sold in Massachusetts. It is also to be noted that barley and dried brewers grain are coming from California by way of the Panama Canal.

The work of this section in connection with the feeding stuffs law for the autumn of 1913 and the winter of 1914 has been published as Bulletin No. 1, Control Series.

(*b*) *The Dairy Law (Acts and Resolves for 1912, Chapter 218).*

It is the intent of this act to promote accuracy in the determination of butter fat by the Babcock test. The act applies to creameries, milk depots, departments of milk inspection and other places where the test is used as a basis for fixing the value of milk or cream. Operators must secure a certificate of competency from the experiment station, all glassware used must be calibrated and machines and apparatus must be inspected once annually.

1. *Examination for Certificates.* — Nineteen candidates have taken examinations and have received certificates.

2. *Inspection of Glassware.* — Six thousand three hundred and thirty-six pieces of Babcock glassware have been tested for accuracy, of which only eighteen pieces were condemned.

Following is a summary for the fourteen years that the law has been in operation: —

Year.	Number of Pieces tested.	Number of Pieces condemned.	Percentage condemned.
1901,	5,041	291	5.77
1902,	2,344	56	2.40
1903,	2,240	57	2.54
1904,	2,026	200	9.87
1905,	1,665	197	11.83
1906,	2,457	763	31.05
1907,	3,082	204	6.62
1908,	2,713	33	1.22
1909,	4,071	43	1.06
1910,	4,047	41	1.01
1911,	4,466	12	.27
1912,	6,056	27	.45
1913,	6,394	34	.53
1914,	6,336	18	.28
Totals,	52,938	1,976	3.73[1]

[1] Average.

3. *Inspection of Machines and Apparatus.* — Mr. James T. Howard, as deputy inspector, has visited and inspected the Babcock machines and apparatus in 80 creameries, milk depots and milk inspectors' laboratories. Only two machines were condemned and conditions were found to be satisfactory in most cases.

Following is a list of creameries, milk depots and milk inspectors' laboratories visited in 1914: —

1. Creameries.

Location.	Name.	Manager or Proprietor.
1. Amherst,	Amherst,	R. W. Pease, proprietor.
2. Amherst,	Fort River,[1]	E. A. King estate, proprietors.
3. Ashfield,	Ashfield Co-operative,	Wm. Hunter, manager.
4. Belchertown,	Belchertown Co-operative,	M. G. Ward, manager.
5. Brimfield,	Crystal Brook,	F. N. Lawrence, proprietor.
6. Cummington,	Cummington Co-operative,	D. C. Morey, manager.
7. Easthampton,	Hampton Co-operative,	W. S. Wilcox, manager.
8. Heath,	Cold Spring,	F. E. Stetson, manager.
9. Hinsdale,	Hinsdale Creamery Company,	W. Solomon, proprietor.
10. Monterey,	Berkshire Hills Co-operative,	F. A. Campbell, manager.
11. Northfield,	Northfield Co-operative,	C. C. Stearns, manager.
12. Shelburne,	Shelburne Co-operative,	I. S. Barnard, manager.
13. Wyben Springs,	Wyben Springs Co-operative,	C. H. Kelso. manager.

[1] Testing done at Massachusetts Agricultural Experiment Station.

2. Milk Depots.

Location.	Name.	Manager.
1. Boston,	Acton Farms Milk Company,	John Colgan.
2. Boston,	Boston Condensed Milk Company,	G. A. Graustein.
3. Boston,	Boston Jersey Creamery,	T. P. Grant.
4. Boston,	Deerfoot Farms,	H. I. Mason.
5. Boston,	Elm Farm Milk Company,	J. K. Knapp.
6. Boston,	H. P. Hood & Sons,	N. C. Davis.
7. Boston,	Llanwhitkell Farms,	E. E. Taylor.
8. Boston,	Morgan Bros.,	A. G. Johnson.
9. Boston,	Oak Grove Farm,	J. Alden.
10. Boston,	Plymouth Creamery Company,	R. Gardner.
11. Boston,	Rockingham Milk Company,	L. G. Sanford.
12. Boston,	Turner Center Dairying Association,	C. E. Small.
13. Boston,	D. Whiting & Sons,	J. K. Whiting.
14. Cambridge,	C. Brigham & Co.,	J. K. Whiting.

2. *Milk Depots* — Concluded.

Location.	Name.	Manager.
15. Egremont, ...	Willow Brook Dairy, ...	E. A. Tyrell.
16. Everett, ...	Hampden Creamery, ...	R. T. Mooney.
17. Great Barrington, . . .	Edgewood Farm Dairy, . . .	C. H. Freeham.
18. North Adams, . . .	Ormsby Farms, ...	W. E. Penniman.
19. Pittsfield, ...	H. H. Prentice & Son, . . .	H. H. Prentice.
20. Sheffield, ...	Willow Brook Dairy, ...	F. B. Perry.
21. Springfield	Tait Bros., ...	G. Tait.
22. Southborough, . . .	Deerfoot Farms, ...	S. H. Howes.

3. *Milk Inspectors.*

Location.	Inspector.	Location.	Inspector.
1. Adams, ...	A. G. Potter.	23. Medford, . . .	W. Joyce.
2. Amherst, ...	P. H. Smith.	24. Millbury, . . .	F. A. Watkins.
3. Andover, ...	F. H. Stacey.	25. New Bedford, . .	H. B. Hamilton.
4. Arlington, . . .	L. L. Pierce.	26. Newton, . . .	A. Hudson.
5. Barnstable, . .	G. T. Mccarta,	27. North Adams, . .	H. Tower.
6. Boston, . . .	J. O. Jordan.	28. Northampton, . .	G. R. Turner.
7. Brockton, . .	G. Bolling.	29. Plainville, . .	J. J. Eiden.
8. Cambridge, . .	W. A. Noonan.	30. Revere, . . .	J. E. Lamb.
9. Chelsea, . . .	W. S. Walkley.	31. Salem, . . .	J. J. McGrath.
10. Chicopee, . . .	C. J. O'Brien.	32. Somerville, . .	H. E. Bowman.
11. Clinton, . . .	G. L. Chase.	33. South Hadley, . .	G. F. Beaudreau.
12. Everett, . . .	E. C. Colby.	34. Springfield, . .	S. C. Downs.
13. Fall River, . .	H. Boisseau.	35. Taunton, . . .	L. C. Tücker.
14. Fitchburg, . .	J. F. Bresnahan.	36. Wakefield, . . .	F. S. Bonney.
15. Gardner, . . .	C. W. Shippee.	37. Waltham, . . .	A. L. Stone.
16. Greenfield, . .	G. P. Moore.	38. Ware, ...	G. E. Marsh.
17. Haverhill, . . .	H. L. Conner.	39. Wellesley, . . .	R. W. Hoyt.
18. Holyoke, . . .	D. Hartnett.	40. Westfield, . . .	W. M. Porter.
19. Lawrence, . . .	J. H. Tobin.	41. West Springfield, .	N. T. Smith.
20. Lowell, . . .	M. Marster.	42. Winchendon, . .	G. W. Stanbridge.
21. Lynn, . . .	H. P. Bennett.	43. Woburn, . . .	E. P. Kelley.
22. Malden, . . .	J. A. Sanford.	44. Worcester, . .	G. L. Berg.

4. Miscellaneous.

Location.	Name.	Manager.
Boston,	Walker Gordon Laboratory,	G. W. Franklin.
Boston,	United Drug Company,	J. H. Lane, chemist.
Springfield,	Emerson Laboratory,	H. C. Emerson.

(*c*) *Water Analysis.*

Water from private supplies is analyzed by this section at $3 per sample, in order to determine its suitability for domestic use. Analysis for mineral content, the bacterial examination and the analyses of waters to determine their suitability for boilers are not undertaken. Samples from public supplies are not analyzed as all matters pertaining to public water supply are by law placed under the direct charge of the State Department of Health. Ninety-three samples of water were analyzed during the past year, the larger number of which came from wells. Waters sent in containers other than those furnished upon application will not be examined.

(*d*) *Milk, Cream and Feeds for Free Examination.*

This section has analyzed a large number of samples of milk, cream and feeds sent to it by farmers and others. The station reserves the right to analyze only such samples as may be of general interest, and will refuse to make analyses where the samples are not properly taken or where such work is more properly the function of a commercial chemist. With the exception of milk and cream, human food stuffs will not be analyzed except where they are direct products of Massachusetts agriculture.

(*e*) *Testing of Pure Bred Cows for Advanced Registry.*

This work has increased to such an extent that at times it is a severe tax upon the regular work of this section. Four men are constantly employed in making Jersey, Guernsey and Ayrshire tests, while for the Holstein work twenty-two men have been used at different times. During the latter part of the year the outbreak of foot and mouth disease interfered seriously with the work. From Dec. 1, 1913, to Dec. 1, 1914, 110 Guernsey, 112 Jersey, 23 Ayrshire and a few Holstein yearly tests were completed. Owing to the disorganized state of the work on December 1, on account of the foot and mouth disease, it is impossible to give with any accuracy the number of cows on test at that time. For the Holstein-Friesian Association there have been completed 189 seven-day tests, 5 fourteen-day tests, 6 thirty-day tests, 2 sixty-day tests and 1 sixty-nine day test, the latter being in connection with so-called semi-official work.

(*f*) *Miscellaneous Work.*

In addition to the work already described, this section has made analyses of a large number of samples of milk, feeding stuffs and feces in connection with experimental feeding and digestion tests. It has also co-operated with other departments of the college and State as follows: —

1. With the Bowker Fertilizer Company in making moisture determinations on corn in connection with the awarding of prizes for yield on a uniform water content.

2. With the agricultural department of the college in making analyses of milk in connection with the awarding of prizes at a dairy show held during farmers' week.

3. With the agricultural department of the experiment station in making analyses of corn kernels to determine the effect of frost and other conditions upon the starch and sugar content of the kernel.

4. With Dr. Gates, the station apiarist, in making determinations of beeswax on 33 samples of slum gum in connection with efficiency tests of the beeswax extraction plant.

4. Numerical Summary of Substances Examined in the Chemical Laboratory.

The following substances have been received and examined: 93 samples of water, 606 milk, 1,489 cream, 1 ice cream, 2 butter, 256 feedstuffs, 226 fertilizers and fertilizer refuse materials, 152 soils, 30 lime products, 33 samples of slum gum, 7 samples vinegar and 5 miscellaneous. There have also been examined in connection with experiments in progress by the several departments of the station, 179 samples of milk and cream, 187 cattle feeds and 318 agricultural plants. In connection with the control work there have been collected 1,307 samples of fertilizers and 924 samples of feedstuffs. In addition, 71 samples of coal have been analyzed for the college heating plant. The total for the year was 5,886. This does not include the work of the research section, where many analyses are made in connection with research problems, nor the work under the dairy law already reported.

REPORT OF THE BOTANIST.

A. VINCENT OSMUN.

The writer of this report has been in charge of the department of botany and vegetable physiology and pathology only since October 13. It has been necessary, therefore, to depend upon other members of the staff for information concerning the particular work conducted by each.

During 1914 the botanical work has been mainly along lines previously reported. Information concerning plant diseases and methods of control has been in increasing demand. Several diseases formerly considered relatively unimportant have come into prominence, and a few diseases previously unlisted as occurring within the State have been reported. Among the former may be mentioned a bacterial root and stem rot of celery, which becomes especially troublesome in storage; a similar rot of onion bulbs, sooty blotch of apple caused by *Leptothyrium pomi* (Mont. & Fr.) Sacc., and anthracnose of snapdragon caused by *Colletotrichum antirrhini* Stewart. The first two mentioned diseases present rather difficult and important problems and need investigating. Sooty blotch of apples is a common disease which usually is readily controlled by spraying. During the last season it was more than commonly prevalent, and several growers reported a large percentage of loss from it. The severity of the outbreak may have been due in part to the dusty atmosphere of a dry summer, but more data carefully collected are needed.

Powdery scab of potatoes was found in several market lots said to have come from Maine, but no occurrence of the disease in Massachusetts-grown potatoes was reported. This disease is a serious one in Europe, and has become established in Canada and Maine. Although Federal inspection and quarantine laws doubtless prevent to a great extent importation of potatoes affected with powdery scab, growers should be alert to detect the trouble in their "seed" tubers, and all suspected cases reported to the station.

The Rhizoctonia disease of potatoes seems to have been quite general throughout the State the last season. The relative importance of this disease in the State is not known, but it has not formerly been considered serious. In several other States, notably Colorado, New Jersey and Maine, it is said to cause considerable loss.

Fire blight of apple and pear trees, though prevalent in the State the last summer, was not as virulent as in 1913, apparently responding to natural check.

The chestnut blight, caused by *Endothia parasitica* (Murr.) Anderson, has continued to spread throughout the chestnut belt, but sufficient data are not at hand to determine whether the spread has been as rapid or the damage as great as in former years. However, it is our opinion, based on limited observation, that this disease has been held somewhat in check by natural causes, possibly climatic conditions, and that the case of the chestnut in Massachusetts is perhaps not so hopeless as it once appeared.

Diseases of tobacco, aside from mosaic disease, have received scant attention by this station. There have been many requests for help in the control of such diseases. The tobacco crop is an important one in the State, and growers are asking that the station co-operate with them in the investigation of some of the more important troubles with which they have to contend. Such work is under consideration, and it is hoped that it may be undertaken during the coming summer.

Diseases for the first time on record as occurring in the State are apple cankers, in which the causal organisms were *Coryneum foliicolum* Fckl. and *Phoma mali* S. & S., both of these fungi being found associated in other cankers with the perfect stage of *Glomerella rufomaculans* (Berk.) Spauld. and von Schrenk; anthracnose of cyclamen, caused by *Glomerella rufomaculans.* var. *cyclaminis* P. & C.; a dry rot of stored potatoes, due to *Verticillium albo-atrum* McA.; silvery scurf of potatoes, caused by *Spondylocladium atrovirens* Harz.; a secondary rot of stored potatoes, due to *Stysanus stemonitis* Cda.; and a fruit rot of egg-plant, caused by *Botrytis fascicularis* (Cda.) Sacc. The cyclamen disease, although previously described,[1] needs further investigation and is now under observation by the writer.

The appearance of the silvery scurf on a seed tuber grown in the eastern part of the State is cause for some concern among potato growers. While not considered serious, the advent of this disease means one more enemy for the grower to combat. This disease appears on the surface of the tuber as a darkened area throughout which are scattered many minute black specks. The latter are sclerotia, similar to those of the Rhizoctonia disease, but very much smaller. The trouble is not easily detected on unwashed tubers but is conspicuous on clean tubers. It causes shrinking, due to loss of moisture through the diseased outer tissue. The disease seems difficult to control, not yielding to ordinary "seed" disinfection as practiced for scab, and growers should, therefore, reject and destroy all seed tubers which show signs of this trouble.

At present the station is largely dependent for plant disease data upon casual reports received in correspondence from persons seeking information concerning remedial measures. The appearance of new diseases, the apparent increased importance of others, and the doubt concerning the importance of still others, suggest a pressing need of improving our facilities for obtaining such information. Other States have made and have under way systematic plant disease surveys. No such systematic investigation has ever been undertaken in Massachusetts, though every one familiar with phytopathological procedure recognizes such work as of fundamental importance.

The number of requests for seed separation and purity and germination tests also has increased. Increased demand from commercial houses for the cleaning and separation of large quantities of seed has made necessary some curtailment of this phase of the seed work. The usual run of seed separation cannot be considered as experimental work, and trained experts employed by the station for investigation should not be obliged

[1] Patterson, Flora A. Disease of Cyclamen caused by a Variety of *Glomerella rufomaculans*. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 171, 12–13, 1910.

to devote time to it. It seems entirely proper that the station should investigate and improve methods, but it is felt that it should be left to the seedsmen to adopt such methods in separating their own seed. This they could do at small initial cost.

Lack of equipment and facilities for making purity and germination tests has made difficult the handling of this work. In this, as in seed separation work, the number of receipts from commercial houses has been excessive.

In connection with the seed work a new device for counting seed [1] and improvements in apparatus for separating tobacco seed have been devised. Methods employed in germination tests are in need of improvement, and it is hoped that investigations looking towards this may be undertaken in the near future.

Miscellaneous experimental work, including spraying, weed eradication, tests of soil and other fungicides, and tests of radio-active substances as fertilizers, has been carried on, and some satisfactory results obtained.

Experiments to determine the effect of certain crude by-products on the control of potato scab [2] were last season transferred from the tile and pots to field plots. Slight beneficial results were obtained, but the work will be continued further before a detailed report is made.

Radio-active substances as fertilizers have aroused much interest, and at the request of a manufacturer, experiments are being conducted in the greenhouse to determine the effect of these materials on seed germination and growth of crops.

Experimental work has continued on the exclusion of roots from tile drains by packing the joints with creosoted excelsior.[3]

Other investigations are under way concerning oil injury to fruit trees and on repellents to prevent gnawing of fruit tree bark by rabbits.

The following Adams fund projects have been authorized: —

1. Study of the physiological reaction of plants to light intensity and moisture in relation to the burning of foliage by sprays and fumigants.

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[1] Clark, Orton L. A Simple Device for Counting Seeds. Science, N. S. XLI, 132, 1915.

[2] Stone, G. E., and Chapman, G. H. Experiments relating to the Control of Potato Scab. Mass. Agr. Exp. Sta., 25th An. Rept., Pt. I., 84–96, 1913.

[3] Stone, G. E., and Chapman, G. H. Experiments relating to the Prevention of the Clogging of Drain Tile by Roots. Mass. Agr. Exp. Sta., 23d An. Rept., Pt. II., 35–42, 1911.

2. Study of the optimum conditions of light for plant response.

3. Mosaic disease of tobacco and allied diseases.

4. Influence of electrical stimulation on nitrogen fixation.

A large amount of data has been gathered in the work on the first project, and results for publication should soon be available.

Progress on the second project has been largely in the development of methods and apparatus preliminary to starting investigation of the main problem.

Investigation of the mosaic disease of tobacco has been under way for some time. The completion of the work awaits the result of certain field experiments to be conducted during the present year. The relative activity of enzymes in healthy and diseased plants has been studied in detail during the last six months. Studies are in progress on methods of control, both by inoculation and absorption of chemicals, and on the effects of different lights, and some apparently favorable results have been obtained. These studies are to be continued during the ensuing year.

Work has begun on the effect of electrical stimulation on nitrogen fixation by *Pseudomonas radicicola* and *Azotobacter*, and satisfactory apparatus and methods for accurate work have been developed. The experiment now being conducted deals particularly with the effects of direct current electricity. It is planned to follow this shortly by similar experiments with alternating current electricity and with static charges. The maximum and minimum currents have been determined more or less satisfactorily.

The results of investigation on electrical injuries to trees, which had extended over a number of years, were published in October as Bulletin No. 156.

REPORT OF THE ENTOMOLOGIST.

H. T. FERNALD.

During the year 1914 little has been attempted along new lines of investigation, a sufficient number of subjects previously undertaken remaining incomplete to occupy all the time available. This report, therefore, indicates mainly progress in research already undertaken at the time of the report for 1913.

A part of the regular work of the station is attending to correspondence with reference to insects. During the past year this has amounted to about 2,800 letters. In most cases the inquiries have been for information about the less well-known insects, which has, of course, involved the expenditure of more time than was the case a few years ago. In a number of instances the information desired was not available, requiring considerable investigation, and in some cases the rearing of material sent in and the devotion of considerable time to the work.

Among the lines of investigation continued were a farther observation of the dates of hatching of the young of our various common destructive scales; a study of the distribution of pests in different parts of the State in order to determine the existence of sections where some might prove of little or no importance: the testing of a number of insecticides, and the completion by Dr. Smulyan of his work on the Marguerite fly, which has now been published as a bulletin from the station.

Experiments for the control of the onion maggot were continued last spring, but an unanticipated scarcity of this insect made these of less value than was anticipated, and the work will need to be repeated and extended this coming season.

Under the Adams fund, farther study of the Sphecidæ as parasites has been prosecuted with satisfactory progress, and spraying with pure materials as a basis for investigations on commercial materials to follow has resulted in the collection of several thousand records on this subject.

The usual amount of care has been given to the collections, in order to keep them in proper condition and protect them from museum pests, and numerous additions, both of adults and to various stages in the life history of many kinds, have been made.

REPORT OF THE HORTICULTURIST.

F. A. WAUGH.

The work in horticultural lines has progressed favorably during the year, but without any special changes in plan or policy. The principal work has been that carried on by Dr. J. K. Shaw, whose separate report is appended. The general plan with regard to the work conducted by Dr. Shaw has been to bring the experiments in plant breeding to a tentative conclusion and to lay greater emphasis upon the research work in pomology, especially upon the extensive experiments in the mutual influence of stock and scion.

Considerable emphasis is also placed upon other practical and scientific experiments in lines of fruit work conducted by Dr. Shaw and Prof. F. C. Sears.

It becomes plainer year by year that the scope of investigations in horticulture should be extended. This desire touches especially the work in floriculture and market gardening, two very important industries of Massachusetts. In spite of their importance very little work has been done directly by this station upon technical problems in these fields.

It seems clear to me that we should make plans to take up definite experimental work in these lines at the earliest practicable moment.

ANNUAL REPORT OF DR. J. K. SHAW.

During the calendar year just closed no new work has been inaugurated but previously established projects have been carried on with a fair degree of success. During February about 9,000 grafts were made for the root and scion project. Some of these made a very good growth, and others did not succeed so well, owing probably to a combination of circumstances, the principal one of which was unusually severe weather during the winter. The two-year old trees belonging to this project were reset on the Tuxbury land and made good growth during the summer. The scions showed a percentage of rooting varying from 0 to 100 per cent., according to the variety. Seedling roots were cut from those showing roots from the scion, and most of them made good growth during the summer. The stock set in the spring of 1913 made excellent growth last summer, and I have hopes that it will show a good percentage of rooted trees. A crop of soy beans was grown on the proposed experimental orchard on the Tuxbury land, plowed in in the fall, and the land sowed to rye. This should result in placing the land in excellent condition for setting the orchard the coming spring. About 2,000 feet of tile were laid in this orchard which should be sufficient to drain the wet portions, with the exception of the south end of the field; this will need to be drained during the coming summer or fall, and nearly enough tile are on hand for the work.

Considerable time was given during the summer to the study of leaf and twig characters on apple trees in order to become thoroughly familiar with the different varieties in anticipation of the study of them as they grow on different roots. It is hoped to continue this in the future, with the possible result of constructing a key by which nursery trees may be identified. A paper on the subject was read before the Society of Horticultural Science at the Philadelphia meeting which will appear in the forthcoming report of this society.

In co-operation with the United States Weather Bureau nine weather observation stations were maintained during the summer months in Buckland and adjacent territory, the Weather Bureau supplying equipment for four stations and the experiment station for the other five. The data accumulated promise to be extremely interesting, and it is hoped to make a preliminary study of them during the present winter. This should be continued for successive years in order to measure the seasonal differences and to confirm results of the several individual years. Considerable time was spent during the winter of 1913 and 1914 upon the study of records secured during the summer of 1913 in the college orchards. These data are being held for consideration and publication with those secured in these outside localities.

The work in plant breeding has been a continuation of that previously carried on with beans, squashes and peas. With the plants grown during the past summer we have records on over 30,000 bean plants, including about 120 crosses, involving something over 20 varieties. This work has resulted in the accumulation of an immense mass of data bearing on the inheritance of pigmentation. This matter is being worked over at the present time, and it is hoped that it may be ready for publication in the spring as a joint publication of Mr. Norton and myself. While this leaves many questions of inheritance of pigments and pigment patterns unsettled, it throws a great deal of light not only upon the manner of inheritance of pigments and pigment patterns, but also upon the mode of inheritance in general.

The work with squashes has been confined to an attempt to isolate pure races, as previous work had indicated that our common varieties of squashes are a miscellaneous collection of heterozygous forms. Plants of the third self-fertilized generation almost completely failed to grow during the past summer. The attempt to grow this generation will be repeated next summer to discover whether this is the necessary result of continued self-fertilization. We were fortunate in having a surplus of seeds of the previous generation which enabled us to repeat the selfing last summer. Individual squashes from each vine were photographed last fall, this having proven the most satisfactory method of recording the different types which are isolated from commercial varieties.

With peas, the work of selecting within the pure lines was continued by growing and measuring of several thousand plants during last summer. A compilation of the results of this third season of selection gives negative results, the difference between the vines selected for length and those selected for shortness being less than during the first year that selection was practiced. This should be continued for a period of years to discover whether this is a permanent result or whether only accidental for this particular year.

The study of the correlation between seed weight and vine length was continued, several thousand plants being grown and measured, each individual seed having been weighed before planting. This shows, as in previous years, the marked correlation between these two characters. It is hoped to prepare the results of this work for publication in the near future.

REPORT OF THE METEOROLOGIST.

J. E. OSTRANDER.

During the past year the work in this department has been continued along the usual lines. Changes in the character of the records or the methods of observation cannot well be made if the results are to be of value for comparison with existing records.

Besides the compilation of the usual data and the arrangement of the records in permanent form, a summary of existing records for twenty-five years was prepared and published as Bulletin No. 153, in June. This bulletin has been sent out to a selected mailing list, and is found useful in answering many inquiries addressed to this department concerning the matter of climate, rainfall, temperature and wind movement.

During the year we have acted as one of the voluntary stations of the United States Weather Bureau, and have furnished special data for publication in the monthly on climatological data of the New England section.

The usual monthly bulletins giving the results of the observations at this station have also been published and distributed from here.

REPORT OF THE VETERINARIAN.

JAS. B. PAIGE, D.V.S.

During the past year the activities in the veterinary department have been directed along lines of correspondence, diagnosis and investigation.

Each succeeding year a larger number of letters is received from the stock owners of the State, asking for information relative to the cause, prevention and treatment of simple ailments that occur among their animals. In every instance the receipt of such communications is acknowledged, and, where possible, the information asked for given. It frequently happens that specimens of diseased material accompany the communication. In such instances it is the practice in the department to examine the specimen and make a report to the sender upon the nature of it. In this way we are able to keep in touch, to a considerable extent, with the nature of the various animal diseases that occur in different parts of the State. In this connection it is particularly interesting to note that avian tuberculosis, formerly known to exist to a very limited extent among the flocks in Massachusetts, has developed extensively within the past few years and has now become quite general in many sections. Not only has the disease been diagnosed in specimens of common fowl sent to the department, but also in ring-necked pheasants from a large flock kept in confinement upon a private game preserve.

The strict investigational studies have been directed toward the development of methods for the diagnosis of bacillary white diarrhœa in adult fowls and the prevention of hog cholera by the use of anti-hog cholera serum.

The method for the diagnosis of bacillary white diarrhœa in fowls is given in full in a bulletin contained in the last annual report of the experiment station. To make a practical test of the method a number of birds was selected from a flock in which there was every evidence to show that there were many individuals harboring infection and producing eggs containing *Bacterium pullorum,* which, when incubated, produced chicks that soon succumbed to an attack of white diarrhœa. Application of the agglutination test to this part of the flock, previously leg-banded for identification, and the subsequent elimination of every individual showing symptoms of infection, gave most gratifying results in the season's hatch of chicks. Of 1,000 chicks hatched from eggs of the tested hens, not one died of white diarrhœa. The previous season, before the bearers of infection had been eliminated from the flock from which eggs were saved for hatching, only 200 chicks, of 2,000 hatched, survived the ravages of disease, 1,800 dying of *B. pullorum* infection. This line of work has been carried on in the department by Dr. G. E. Gage and his assistants.

The hog cholera investigations were started in January, 1913, in co-operation with the Massachusetts Department of Animal Industry, and are in progress at the present time. Since the above date many experiments of a strictly scientific character have been conducted at the experiment station, and also practical tests made in several different herds of hogs, to determine the value of anti-hog cholera serum as a cure and preventive of hog cholera. During the period that the work has been in progress no less than 3,283 hogs, on fifteen different farms in the State, have been treated. While the results have not been uniform in the different herds, they have, on the whole, proved satisfactory, and promise eventually to provide a method for the protective treatment of hogs against cholera infection. Little or no curative effect has been observed from the use of serum on hogs actually suffering from cholera.

REPORT OF THE POULTRY HUSBANDMAN.

J. C. GRAHAM AND H. D. GOODALE.

Steady progress has been made on our original projects. A new viewpoint of the problem of egg production has been secured which leads to the belief that it will have to be studied analytically, considering the factors of broodiness, age, egg cycles, rate of laying, longevity, maturity, each by itself as far as possible. Certain families are better producers on the whole than others. That the male is a factor in determining the egg production of his daughters appears to be demonstrable, but not in the same sense as described by other students of the problem. The winter egg cycle in Rhode Island Reds, if present at all, is not marked off from the spring cycle by a fall in egg production. The stimulus that induces the hen to visit the nest is not always associated with the deposition of an egg. Additional data substantiating the individuality among fowls in relation to the hatching quality of their eggs and viability and rate of growth of chicks have been secured. Further work on morphogenesis has been done, particularly in relation to the influence of the primary sexual organs to the secondary sexual characters. In one instance an apparently successful graft of ovaries was made in a castrated cockerel, feminizing it to a large degree.

A new building 18 by 72 feet has been provided, having laying accommodations for 300 hens. This gives us a total capacity for 450 laying birds. By means of movable partitions the new building can be transformed into a breeding house for pen matings.

Mr. Sayer resigned the first of October. Late in December a satisfactory man was finally secured, Mr. Austin Brown. In the meantime the egg production was decidedly unsatisfactory, due perhaps to improper care.

ELECTRICAL INJURIES TO TREES.

GEORGE E. STONE.

Introduction.

In 1903 there was issued from this station a bulletin dealing with some new phases of the subject of electrical injury to trees.[1] This bulletin has been out of print for some time, and as many new observations — the result of years of careful study of the influence of electricity on plants — have been made, it has been thought wise to issue another edition. Many people are quite unfamiliar with certain types of injury from electricity occasionally to be found, and even those directly responsible often do not realize how serious the harm done is likely to prove.

The increase in electric railroads, electric lighting systems and telephone lines, whose wires are usually located near the tree belts of our cities and towns, has made necessary a lamentable amount of disfiguring pruning. When strung too close to trees, wires also often cause serious injury by burning, and sometimes mechanical injury is done; and even lightning discharges will cause harm when guy wires are attached to trees. (See Fig. 1, Plate I.)

Both the alternating and direct currents are used. They produce different physiological effects on plant life, the alternating current apparently being less injurious than the direct; and when either is used at a certain amperage it acts as a stimulus to the plant, and growth and development are accelerated.

There are minimum, optimum and maximum currents affecting plants. The minimum represents that strength of current which just perceptibly acts as a stimulus, and is a very insignificant current. The optimum is that producing the greatest stimulus — about .2 milliamperes — and the maximum, that causing death. (See Fig. 3.) Between the optimum and the maximum there is a strength of current that causes retardation in the plant activities, this being represented between R and MX in Fig. 3. The maximum current necessary to cause death is very variable. The direct current has a less stimulating effect than the alternating, and on account of its electrolyzing effect is capable of causing more injury to vegetable life than the alternating current.

Most of the injury to trees from trolley or electric light currents is local; *i.e.*, the injury takes place at or near the point of contact of the wire with the tree. This injury is done in wet weather when the tree is covered with a film of water, which provides favorable conditions

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[1] G. E. Stone, "Injuries to Shade Trees from Electricity," Bul. No. 91, Mass. (Hatch) Agr. Exp. Station, 1902.

for leakage, the current traversing the film of water on the tree to the ground. The result of contact of a wire with a limb under these conditions is a grounding of the current and burning of the limb due to "arcing." The vital layer and wood become injured at the point of contact, resulting in an ugly scar and sometimes the destruction of

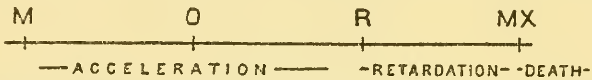

Fig. 3.— Diagram showing range of electric current affecting plants. M = minimum; O = optimum, or current producing greatest stimulus; MX = maximum, or death current; R to MX = retardation current.

the limb or leader. In a large number of tests made by the aid of sensitive instruments with guy wire and other connections of wires to trees we have never found any leakage during fair weather, or when the surface of the tree is dry. Since the amount of current that can be passed through a tree depends upon the resistance and electro-motive force, we shall consider this resistance at some length.

Electrical Resistance of Trees.

The electrical resistance shown by trees is quite great, otherwise more injury might result from contact with live wires. The following table (I.) gives the electrical resistance of 10 feet of a maple and elm, each tree being about 2 feet in diameter and the electrodes 10 feet apart. These resistances were determined by a Western Electric Company combination bridge rheostat and galvanometer, and a large battery. Other resistances, however, have been obtained by means of the electro-motive force, and a known current passed through the tree, the two methods agreeing in their results quite closely. The table, which is taken from one of our previous publications,[1] is one of many.

Table I. — *Showing Average Electrical Resistance (in Ohms) of Maple (Acer saccharum Marsh) and Elm (Ulmus americana L.) covering a Period of nearly Three Months. Resistances taken on the North, South, East and West Sides of the Trees about Midday. Electrodes 10 Feet Apart.*

Tree.	Month.	East.	South.	West.	North.
Maple,	April,	18,550	18,185	20,500	20,800
	May,	21,075	20,550	21,650	24,500
	June,	19,775	19,761	21,883	22,550
Elm,	April,	24,300	26,075	25,700	24,275
	May,	13,025	15,750	14,825	17,375
	June,	14,992	18,608	17,508	17,883

[1] Electrical Resistance of Trees, G. E. Stone and G. H. Chapman, 24th Ann. Rept. Mass. Agr. Exp. Station, 1912, Pt. I., p. 144.

It will be noted that these resistances were taken on the east, south, west and north sides of the trees, and represent averages of weekly observations. The lowest resistance (data not given in the table) obtained from the maple was 14,000 ohms, and the highest, 33.000 ohms. In the case of the elm the lowest resistance was 6,300 ohms, while the highest was 29,400 ohms. These resistances are relatively low, for in cold weather they often exceed 100,000 ohms. The lower resistance in all cases corresponds to periods of high temperatures, and the highest to periods of the lowest temperature. The difference shown by the various sides of the tree is also related to temperature.

As might be expected, there is considerable difference in the electrical resistance of various trees as well as of the different tissues found in trees. The heartwood, sapwood. cambium, bark and sieve tubes possess quite different properties and functions, and their electrical resistance would naturally vary to a large extent. The living cells containing protoplasm, such as are found in the cambium, present the least resistance, as shown by various observations on lightning discharges. The minute burned channel, caused by comparatively insignificant lightning discharges, follows down the cambium, indicating that this is the line of least resistance. Moreover, by driving electrodes into a tree to different depths and measuring the resistance it can be shown that the least resistance occurs in the region of the cambium.

The electrical resistance, however, may average throughout the year 25.000 ohms more or less in 10 feet of the trunk of a large maple tree. This constitutes a comparatively high resistance. The resistance of the sapwood is very much greater, and probably that of the heartwood is even higher than that of the sapwood.

In determining the electrical resistance it is necessary to know the path or course of the current, and the only manner in which the resistance of different tissues can be determined accurately is by isolating the tissues. By girdling a tree and scraping the trunk down to the solid wood we can get the resistance of the wood. Mr. G. H. Chapman found the resistance of a freshly cut rock maple stem, 1½ inches in diameter, to be 70,000 ohms with the bark on, but 150,000 ohms when the bark was removed. The electrodes were 1 foot apart. Some of our experiments indicate that next to the cambium the phloem has the least resistance, followed by the sapwood. The outer bark appears to offer the most resistance, but when wet the resistance may be somewhat decreased owing to the less resistant film of moisture on the bark. The resistance obtained from an elm tree in summer, with the electrodes 10 feet apart and in contact with the cambium, was 10,698 ohms, whereas when the electrodes were inserted into the middle of the cortex or phloem we obtained 11,300 ohms resistance. When driven ¼ inch into the wood the resistance was 98,700 ohms. The outer bark gave 198,800 ohms resistance, but when the electrodes were inserted slightly deeper into the bark we obtained 109,900 ohms. It must not be understood, however, that these readings gave the electrical resistance of 10 feet of the various tissues enumerated except in the case of the cambium, since if these tissues were isolated the resistance would be much greater in some cases. They show that there is much difference in the resistance of different tissues, but in all cases we obtained merely a resistance of the cambium, together with that of a part of the other tissues which the current had traversed from its various points of entrance to the cambium. It is quite evident from our observations on the resistance of trees that the cambium gives the least resistance, the phloem next, and it is not at all unlikely that in some trees there may be some variation in this respect.

The resistance given by small tree trunks and woody stems, even for small distances, is quite large. About 4 feet of a young pear tree, including the root system, with a maximum diameter of stem equal to 1 inch, gave a resistance of about 300,000 ohms, and the resistance given by a tobacco plant, in which the distance between the electrodes was only 14 inches, was much higher (110,000 ohms to 165,000 ohms) than that shown by most trees at corresponding temperatures.

The water and various salts in the living plant undoubtedly play a rôle in resistance, and it might be expected that the various plastic substances would influence resistance.

The cambium ring is very insignificant in size, and even on a large tree the total area is small. In all probability it is the protoplasm itself which offers the least resistance to the transmission of an electric current; and even if there were no continuity it would be necessary for the current to pass through a great many cell walls even for comparatively short distances on the trunk. In case the protoplasm was continuous or there existed continuity, the strands would be so very small that they would undoubtedly offer some resistance. Whatever conditions prevail, trees show relatively high electrical resistances, a feature which is no doubt of some biological importance as trees are often struck by lightning. The high resistance of trees, therefore, is undoubtedly a protection in case of lightning strokes, since often the heat developed is enough to do only slight injury. On the other hand, if trees possessed tissue with relatively small electrical resistance they would be much more subject to injuries from burning from lightning strokes, and would be more seriously affected by currents from high-tension wires. The electrical resistance of trees is so high that it is doubtful whether injury ever occurs to them from contact with low- or even high-tension wires except that produced by grounding when the bark is moist. Any escaping current from transmission lines that can be transmitted even through the least resistant tissue is likely to be insignificant.

Effects of Alternating Currents.

The alternating current systems employed for lighting purposes vary greatly in their potential. Cases of burning from alternating currents are more numerous than those from direct currents because trees are brought into more frequent contact with the wires, and owing to the higher potential more leakage is likely to occur. The high and low voltage lines may vary from 100 to 100,000 volts. The high-tension systems are invariably constructed across country, and are naturally not brought into very close proximity to shade trees. No injury to trees whatever occurs from the low voltage (110-volt) lines, but the lines of higher potential found on streets constitute a source of danger to trees. The higher the electrical potential the more dangerous the wires become to trees, for owing to the lessened effectiveness of the ordinary insulation, more leakage occurs and consequently greater opportunity for burning.

The effects of alternating currents on trees are local, producing injury only near the point of contact with the wire. Such contact results in death of that part of the tree, and if it is a leader or a large limb it usually has to be sacrificed. In no case, to our knowledge, has an alternating current caused the death of a tree, although it may burn or disfigure the tree so badly that it amounts to practically the same thing. It is doubtful whether the current from a fairly high potential wire would kill a large tree under any circumstances. It is different in the case of small plants, as has been frequently demonstrated in the laboratory, although the current must produce heat enough to kill the protoplasm. Owing to the close relationship between the maximum temperature required to kill a plant and that induced by electrical current, the collapse of the plant tissue in such cases is therefore due to the heat rather than to any specific electrical shock, as it is possible to pass the same current through larger plants where heat is not generated without causing any collapse of the tissue. The ordinary house circuit wires are perfectly harmless to trees, and it seems strange that a judge could render a verdict to the effect that an ordinary insulated 110-volt house circuit was responsible for the death of a tree whose terminal branches were located within 3 feet of it. This is the only court record of which we know where such a judgment has been given.

Very high-tension line wires are not provided with insulation and are known to affect the atmosphere surrounding them to a considerable extent. Any increase in the electrical potential of the atmosphere if not too high would favorably affect vegetation in general.[1]

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[1] There is evidently much difference in plants in this respect. A crop of radishes showed a gain of 57 per cent. when subjected to an average atmospheric potential of 167 volts, whereas an electrical potential equal to 500 or 1,000 volts is beyond the stimulation zone for some plants (16th Ann. Rept. Mass. Agr. Exp. Station (Hatch), 1904, p. 31).

It has been suggested that arc lights are injurious to trees, although we have never seen any cases of injury. It is well known that electric light is different from sunlight in its effects on plants, and it stimulates photosynthesis in proportion as it resembles sunlight in its rays. Some artificial lights contain rays that may act injuriously on small plants and in other ways modify their development, but even if a tree in close proximity to such a light should die it is no proof that it has been injured by this cause, as there are so many other causes for the death of trees.

Effects of Direct Currents.

Most of the direct currents affecting trees are those used for operating electric railroads. Trolley feeders may be at 500 to 550 volts. Ordinarily the burning from direct currents is similar to that produced by the alternating current in being largely local or confined mainly to the point of contact with the wires. The feed wires cause no burning except when the tree is moist, in which case grounding takes place.

We have made a number of experiments, using large trees and small herbaceous plants, with direct currents from electric railroads showing the amount of current passing through trees, etc. In a number of instances a wire was passed from the tree to the rail or ground, and another wire was connected to a bare feed wire (450 to 500 volts) leading to some other portion of the tree, a milliammeter being placed in the circuit to obtain the actual current. The results were as follows: a young pear tree, 2 feet 8 inches in height, and 1¼ inches in diameter at the base, which had been growing one year in a box 14 by 16 by 9 inches, and provided with a copper plate in the bottom in direct contact with the roots, showed a current of 2.2 milliamperes (1/454 ampere) when one electrode leading to the rail was connected with the copper plate, and the other leading to the feed wire joined the top of the tree; 16½ feet of a maple tree 18 inches in diameter gave 25 milliamperes (1/40 ampere), and 7 feet of the same tree gave a current of 45 milliamperes (1/22 ampere). Connections made with a poison ivy (*Rhus toxicodendron* L.) plant growing on a tree showed in most cases similar results when the electrodes were inserted into the stem 2 inches apart. A stem ¾ inch in diameter gave a current equal to 4.4 milliamperes (1/227 ampere); ½ inch in diameter, 25 milliamperes (1/40 ampere); and another of the same size, 50 milliamperes (1/20 ampere). In the latter case, and some others not included here, the currents went down from 50 milliamperes to nothing almost instantly. From these experiments with ivy it appears that the current burned out the cambium or vital layer of the stem, leaving the dry and highly resistant wood which was unable to transmit a perceptible current.

In another experiment young sunflowers and tomato plants grown in 3-inch pots, with copper plates at the bottom, were treated from a direct current dynamo which generated an electro-motive force of about 60 volts. The plants were from 6 inches to 2½ feet high, and ⅛ to ¼ inch in diameter. When the current passed through 16 inches of the stem and copper plate to the bottom of the pot, a sunflower plant 3/16 inch in diameter gave scarcely perceptible readings; but when the current passed through only 1 inch of the stem and root to the copper plate at the bottom, the maximum current was 2/6 milliampere (1/384 ampere). This caused blackening and death of the tissues, perceptible a few hours afterwards about the points of insertion of the positive electrodes into the stem, and the plant was girdled for about two-thirds of its circumference. Very similar results were obtained with other sunflower plants treated in the same way. A plant 30 inches high and ¼ inch in diameter, subjected to a current of 10 milliamperes for some minutes, was not injured to any extent. In this case the current passed through about 1 inch of stem and ½ inch of soil. A young, succulent tomato plant, ⅛ inch in diameter and 5 inches high, was instantly killed when treated in the same manner with a current of 20 milliamperes, and a current of 2 and 3 milliamperes of 30 to 60 seconds duration accomplished the same result. In all the tomato plants considerable heat was developed. In one case in which an alternating current was used the plant lived for a number of days after the tissues had changed color and the plant had collapsed, as the vascular bundles or water-conducting tissues were not injured.

In the experiments cited all the injuries occurring were due to the effects of heat generated by the current. The experiments also showed that the strength of current which will kill one plant will produce not the slightest effect on another; in other words, the maximum current for each individual varies materially. Small, tender plants possess a maximum much below that of woody plants. The experiments were all carried on under normal moisture conditions; but when trees with a more or less thick bark are drenched with rain the conditions are quite different. A large maple tree which was in circuit with a feed wire (500 volts) and rail of an electric road gave a current equal to 70 milliamperes (1/14 ampere) with the electrodes placed vertically 1 foot apart. These connections were left on the tree for several months. The observations were made on dry days, and no heat developed with this current. During periods of wet weather considerable heat always developed, especially at the positive electrode, but not enough to melt the soft solder which connected the wires with the electrodes.

Examination of the tree ten months later showed that a portion of the tissues near the electrodes had been killed. After removing the dead bark an oval space 6 by 11 inches was found to be dead about the positive electrode and a space about 1½ by 3 inches near the negative electrode. The burned area about the positive electrode was about

95 per cent. greater than that occurring about the negative electrode. In each case it extended about twice as far above and below the point of contact as out to the sides of the electrodes, thus showing a tendency of the current to spread laterally as well as vertically, but more largely vertically.

The immediate area around the electrodes was more affected than that further remote. There was an area of tissue about 5 inches long between the large and small oval burning that was uninjured, showing that burning was confined about the electrodes. The current traversing the film of water on the bark between the electrodes was not sufficient to destroy all of these tissues at that point.

If a milliammeter had been placed in the circuit when the tree was wet a greatly increased current would have been detected, since the current in this case traversed the less resistant film of moisture on the bark. But the electrical resistance of the vital layer under such conditions would remain practically the same as when the tree was dry. The burning and injury in this case resulted from the heating of the film of moisture, which became so intensely heated that the vital tissue was destroyed, especially near the point of insertion of the electrodes. The more the film became heated the greater was the lessening of the resistance and increase of the current.

Practically all of the burning of trees from either alternating or direct currents occurs in this way, since the high electrical resistance characteristic of trees does not permit injurious currents to pass through their tissues.

Death of Trees from Direct Current.

Instances are known in which large trees have been killed by direct currents used in operating electric railroads. So far as we know attention was first called to these cases in Bulletin No. 91, issued by this station, but since the publication of this bulletin other cases have been observed in which the escaping current had burned and girdled the trunks for a distance of 5 to 10 feet from the base, the point of contact of the feed wire with the limb 18 or 20 feet above, showing little or none of the characteristic local burning effects usually observed in ordinary cases of grounding. In fact, the difference between the burning from direct currents in these cases and that from ordinary cases of electrical injury may be seen at a glance. On electric railroad systems the so-called positive current almost always traverses the overhead feed wire where the injury (burning) takes place. This differs only slightly from that produced by low-tension alternating current wires. In all cases of death from direct current electricity that have come to our notice the rail was positive, and the overhead feed wire was negative, constituting what is called a "reversed polarity." How common this practice is we cannot say, but apparently it has been done intentionally at times to prevent electrolysis as well as unintentionally by various companies, and is responsible in quite a few instances for the death of shade trees near electric railroads. There is much greater opportunity for extensive burning in the case of reversed polarity than in the regular systems employed. The moisture conditions of the soil and bark are such as to reduce the resistance, and in consequence the film of water and water-soaked bark become intensely heated, destroying the living tissues and girdling the tree to a considerable distance. The part of the trunk towards the rail is almost invariably the most severely affected. In the cases observed some years ago, where the current was reversed, there were no deep burning effects on the tree either above or below, — the rule when the overhead feed wire is positive (as is usually the case) and in direct contact with the tree. Moreover, the affected areas about the base of the tree are decidedly larger than when a positive overhead feed wire comes into contact with limbs. The entire area between the base of the tree and the overhead wire is not, as a rule, affected, although the extent of injury may vary somewhat. The injury from burning is confined to a space around the overhead wires, and also to the base of the tree. On the elm shown in Fig. 8, Plate IV., the burning was caused by a reversed system, and there was only slight injury at the point of contact with the overhead wire, while at the base about 6 or 7 feet of the tree was affected. This injury takes place when the soil and bark of the tree are moist, and may occur during a single period of excessive moisture, or intermittently. In some instances trees show serious effects a short time after the current has been reversed, when the bark will become loose and later fall off. The writer has observed both elms and maples — some of them 2 feet or more in diameter — which have been killed in this way. In some cases the trees were not more than 3 feet from the rails, while in others the distance was considerably greater.

In one well-planted city having extensive street railways, 51 trees were reported killed or so badly injured as to be of no value, 67 had large limbs removed, and many more were saved by removing limbs likely to come into contact with the wires. According to Mr. G. A. Cromie,[1] who had these under observation, the injured trees were in some cases located from 200 to 1,000 feet from the track. Some of the injury took place on streets having wires but no electric railways, and it is surmised that the ground connections were made through several pipe lines, located near the trees, which led very close to the electric railway. Mr. Cromie states that the effects on the trees were noted shortly after the street railway had changed its system, *i.e.,* using the rail to carry the positive, and the overhead wire the negative or return current. The trees in contact with the overhead wire became electri-

[1] G. A. Cromie, "Scientific American" supplement, No. 1985, p. 40, Jan. 17, 1914.

cally charged, and when wet it was impossible for linemen to work on them. Under these conditions the insulation was much less efficient, and even wooden sleeves imbedded in coal tar and rubber proved of small use in preventing leakage, but otherwise there was little or no trouble from burning.

We were able to examine only a few of these trees, most of them having been removed at the time of our observations; but a large percentage showed a characteristic burning at the base and the bark was burned off in some instances to quite an extent. One limb that had been in contact with the negative feed wire was found dead, but the tissue at the base of the trunk was normal. Dr. J. W. Toumey, director of the Yale Forestry School, who examined many of these trees, found a disintegration of the wire where it came into contact with the limbs, apparently due to electrolytic action, and chemical analysis showed the presence of copper and zinc in the tissues of the wood that had been in contact with the negative or overhead wire. Dr. Toumey believes that in such cases the disintegration of the copper wire and the absorption of the copper by the tissue were responsible for the death of the limbs. If true, this entirely new state of affairs would indicate that the electrical injury from direct currents not only arises from heat but also from the electrical disintegration of metals. which may poison the tissues. These observations demonstrate that we have a variety of conditions to deal with in considering the effect of direct current electricity on trees, and these phenomena may be summarized as follows: —

Burning and injury to plant tissue are much more noticeable at points with a positive potential[1] than at points with a negative potential.

When the rail is at a positive potential the overhead wire, which touches some part of the tree, is negative, and the bark and soil are saturated with moisture, and a circuit is formed by means of this surface moisture.

The moisture conditions and the electrical resistance, etc., at the base of the tree are different from those above, therefore a larger area of tissue is affected by the positively charged rail.

As the bark becomes heated through the film of water, the electrical resistance is reduced and the current increased to such an extent that the vital layer is destroyed.

The actual current passing through the inner tissues must necessarily be insignificant, and when there is a film of water on the bark, probably no current passes through the cambium; furthermore. the moist soil between the rail and the trunk of the tree becomes a better

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[1] Positive electro-static charges have a more stimulating effect on plants than negative charges, and retardation of growth and injury to the cells are more pronounced. The phenomena associated with the positive and negative galvanotropic bendings of roots may be explained in this way (24th Ann. Rept. Mass. Agr. Exp. Station, Pt. I., p. 144, 1912).

conductor for the current than the roots. The actual injury, therefore, is done by the current traversing the film of water rather than any of the inner tissues. The maximum heat and the areas most affected are near the base of the trunk.

In regard to the possibility of injury to large trees by direct currents passing directly through them, experiments show that what holds true for alternating currents is true also to a great extent of direct currents. However, it would require a voltage much higher than that furnished by most electric railways at the present time.

It might be possible for direct currents to produce a weakening effect on the vital activities of the tree, although not causing any perceptible burning. If, for example, a tree was subjected to a strength of current equivalent to that represented between R and MX in Fig. 3, page 2 (retardation current), there might occur a disintegration of the cell contents, causing the tissues to become abnormal and finally die, but the electrical resistance of trees is so great that a quite high potential would be necessary. If the potential of the electric railway systems were increased ten or twenty times it is possible that some injury might result to trees even under ordinary moisture conditions.

Probably the amount of ground leakage occurring through imperfect rail connections would not cause any perceptible injury to trees. Nor is there any direct evidence that lightning arrestors when placed near trees cause any injury by discharges. However, the guy wires used by electric railway systems are a source of danger from lightning, and we have observed cases where large limbs have been destroyed and the trunks of the tree badly lacerated by electrical discharges from these wires.

On the whole, the cases of death to trees from electricity are by no means so numerous as is generally believed. Because a large number of trees near electric roads, etc., often look sickly it must not be concluded that electricity is always the cause. In cities and towns, where most of these unhealthy specimens are found, there are innumerable destructive factors for trees to contend with. It is quite essential in diagnosis work, therefore, that all of these factors be taken into consideration before a definite opinion in regard to the cause of any abnormal condition is formed.

Electrolysis.

Direct current electricity is frequently responsible for electrolysis of gas and water mains, and lead coverings of underground telegraph circuits are often affected. The trouble is often so serious that the iron gas and water pipes (Fig. 9, Plate III.) become corroded and eaten with holes in a few weeks or months, causing leakage. When gas mains are affected by electrolysis, the gas escapes and permeates the soil, so that electricity sometimes becomes a primary and gas a secondary factor in the death of trees.

The phenomena associated with electrolysis are often complex and difficult to do away with entirely, according to expert electricians, but much of the trouble can be eliminated by proper bonding of the rails of electric roads and the grounding of different systems.

Electrolysis is more common in wet than in dry soils. Cases are on record where severe electrolysis has taken place 700 or more feet from the source of leakage. It more often becomes troublesome in cities where numerous railways and public-service corporations of all kinds make use of the streets. We have observed cases where plants have been stimulated and their growth increased by escaping electricity in the soil.

Lightning.

The common effects of lightning strokes on trees are so well known that it is not necessary to dwell upon them here; but lightning does not always strike a tree in the same way, and the peculiar effects sometimes produced are often interesting. Very powerful discharges of lightning act somewhat like an avalanche, causing a severe shattering of the tissue, while less powerful discharges may remove a strip of wood only a few inches wide and 1 or 2 inches thick. Lightning often takes a spiral course, following the grain of the wood, which is sometimes very irregular. Even when strips of wood 4 or 5 inches wide and 2 or 3 inches thick are removed, in which case the electrical energy is enormous, the path of the discharge is shown only by a dark-colored streak 2 or 3 millimeters wide.

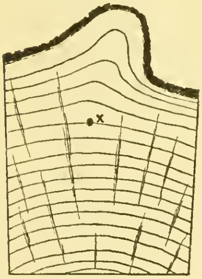

Fig. 11. — Cross-section of elm shown in Fig. 10; X = small dead area corresponding to path of lightning discharge.

Sometimes trees are killed outright by lightning without being shattered or displaying any other of the common effects. In such cases the discharge is apparently dispersed so as to cause no visible mechanical injury to the tree, but the girdling of a large or small area of the living zone or cambium layer of the trunk would be sufficient to cause its death. However, in a very large number of instances neither death nor mechanical injury of any importance takes place. Hundreds of trees are annually struck by lightning that never show any effects except to those capable of interpreting the small narrow ridges which later make their appearance on the trunk. (See Fig. 10, Plate V.). In such cases the lightning discharge follows the line of least resistance, — the cambium zone, — burning a small channel usually about 1 millimeter in diameter. The tissues surrounding the channel are apparently not injured, but the annular rings which are later formed outside the burned channel are much broader, resulting in the formation of a ridge on the bark. (See Fig. 11.)

Earth Discharges.

There are many cases of lightning that are apparently earth discharges. Their effect on the tree is quite characteristic and not at all similar to the ordinary forms of lightning strokes. Our attention was called several years ago to some shade trees to which lightning had apparently caused some injury. These trees were maples 5 to 18 inches in diameter, growing in soil composed mainly of gravel containing oxide of iron, and underneath this a stratum of quicksand. A considerable number of the trees showed the effects of repeated earth discharges, in some cases becoming so disfigured that they had to be replaced for the third time. These discharges occur during thunder storms, and those who have observed them for many years relate that they give rise to a dull, characteristic report resembling that caused by throwing a wet cloth on a hard surface. The whole tree is not affected as a rule, as the lightning stroke seldom follows up the main trunk, but discharges at the points of several branches. As a rule, however, one side of the trunk and one or more of the limbs on that side are affected and the symmetry of the tree destroyed. The first indication of the discharge is shown by the immediate wilting and subsequent death of the leaves of the affected limbs, which also die later. In the course of time cracks similar to those caused by frost, and later, ridges due to healing, will be seen on the trunk, showing the path of the discharge, and occasionally when the injury is considerable the bark falls off near the affected part of the tree. The limbs, however, are not always killed, frequently splitting (see Fig. 12, Plate V.), and a cracking of the wood for some depth is now and then observed on the trunk and limbs along the path of discharge.

A very much larger number of trees show earth discharges than is realized. MacDougal[1] has called attention to some trees which appear to have been injured by earth discharges.

Whether the chemical composition of the soil has any particular bearing on earth discharges is not positively known. It is known, however, that there frequently exist great differences in the electrical potential between the earth and air during thunder storms, and that the electrical conditions of the atmosphere and earth may change instantly from negative to positive. Some observations made in our laboratory with a Thomson self-recording quadrant electrometer and

[1] Journal of the N. Y. Bot. Gardens, Vol. III., No. 31, July, 1902.

water-dripping collector show that the electrical potential of the atmosphere varies from a negative charge of 75 volts to 300 positive at various times at a distance of 30 feet from the ground; and our records show that most of the time the atmosphere is charged positively. It is also known that trees occasionally discharge sparks at their apices, showing that insignificant earth discharges occur through trees; and when the soil in which potted plants are growing is charged electrostatically, small sparks are thrown off from the leaves. Earth discharges through trees, whether strong or weak, appear to be similar in nature, and may be associated with changes in the potential of the earth and atmosphere. The high electrical resistance shown by plants in general, as already stated, serves as a great protection against death from lightning and electric currents.

Susceptibility of Different Trees to Lightning Stroke.

There has always been great difference of opinion in regard to the susceptibility and non-susceptibility of various trees to lightning, and the data on the subject gathered from this and that source are altogether too meager to admit of reliable statistics. But it is known that the location of the tree, nature of the soil, elevation, etc., are of great importance in determining susceptibility to lightning.

It has already been pointed out that electrical resistance is influenced by temperature, and the percentage of moisture in the tissues is also an important factor. During thunder showers trees become more or less drenched with rain, and according to Stahl,[1] the more thoroughly wet the tree is the less susceptible it becomes to lightning stroke. He bases his observations on the fact that smooth-bark trees like the beech and others, which are considered more immune to lightning, become thoroughly wet during storms, while the oak and other rough-bark trees do not. Stahl's idea, therefore, is that smooth-bark trees possess a better water-conducting surface and have a tendency to equalize the electrical tension existing between the atmosphere and the ground, so that they are rendered less susceptible to lightning. His deductions were based upon experiments with electrical discharges made with the bark of different species of trees containing various percentages of moisture. He further observed that vertical limbs were more likely to become drenched than horizontal, and that the lenticels and stomata play a rôle in the equalization of the differences in electrical potential existing between the tissues and the atmosphere, etc. There appears to be no difference in the electrical potential under deciduous trees and in the open air when there is no foliage, at corresponding heights, and the electrical potential will average 40 per cent. less under the foliage of trees than in the open air when the foliage is developed.

[1] Stahl, E. Die Blitzgefährdung der verschiedenen Baumarten, Jena, G. Fisher, 1912.

The potential of the air is usually negative, although occasionally changing to positive. In the case of coniferous trees, however, like the Norway spruce,[1] we found that the potential under the foliage was invariably positive or similar to that of the earth, which may be explained on the theory that conifers are constantly discharging positive electricity to such an extent that the air surrounding them becomes charged similar to the earth. To what extent the film of water on the bark is capable of equalizing the difference in electrical potential in the air surrounding the trees, as well as the ground and in the tissues themselves, has not been wholly determined, but we had difficulty in obtaining potential readings under the foliage of elms in wet weather in our experiments covering two summers. This may in part be explained by the improper installation of our collector. It is not unlikely that the film of water on the bark of trees during such periods would have a tendency to affect materially the potential of the surrounding air, and possibly to equalize the electrical tension. The subject should have further investigation, but we believe that it is possible to protect trees from injury by lightning, whether they be atmospheric or earth discharges.

Methods of preventing Injury to Trees from Wires.

The constantly increasing use of electricity for various purposes makes necessary a more extensive use of wires which have become a great menace to shade trees. The appearance of streets is also hardly improved by the increased number of poles and wires, and the legal restrictions as to the height, distance apart, etc., of the wires of the telephone, telegraph, trolley and electric light companies make the problem of maintaining shade trees on the same street with public-service corporations a serious one. Of all the troubles with which tree wardens have to contend the wire problem is often regarded as the worst. Notwithstanding the strict laws which some States have adopted in regard to injuring shade trees, the agents of some public-service corporations often have little regard for trees or the laws respecting them. Where 40-foot poles must carry the wires of three or four public-service corporations there can be little or no opportunity to preserve the natural symmetry of shade trees, especially when low branching maples and other trees are planted on the same side of the street with the wires. There is less interference from limbs with low than with high-tension wires. Trees like the elm, whose branches form acute angles, offer less obstruction to wires than maples; but not all streets, of course, are planted with elms, which may be as well, considering their susceptibility to various pests and unfavorable climatic conditions.

The best solution of the wire problem lies in burying the wires. This

[1] Mass. (Hatch) Agr. Exp. Sta. Rept. 1905, p. 14.

has been done to quite an extent in large cities, especially in the business sections, the telephone corporations having adopted this system to a much greater extent than the electric light companies. It is an expensive system, however, and those who so strenuously advocate its adoption do not always consider that in the end it is the patrons who have to pay for it.

Another method of preventing wire injuries is the erection of high poles to bring the wires over the trees. This is sometimes done, especially where the trees are young or of a species that naturally grows low, when a very high pole would be sufficient to clear them for many years. The cable system may be used for telephone wires, and much injury to trees prevented. Large cables are rather expensive to install,

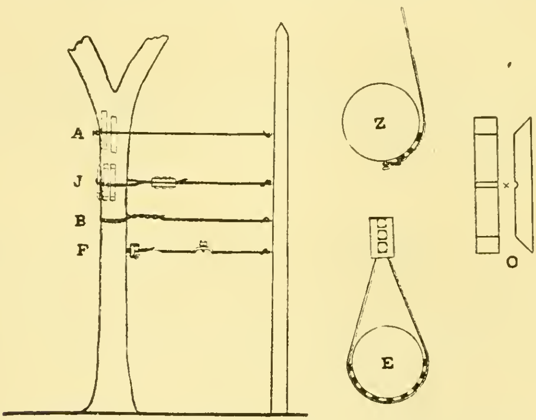

FIG. 13.—Showing different methods of attaching wires to trees: *a*, wire attached to lagbolt, and tree protected from it by wooden blocks; *z*, cross-section of same; *b*, wire loops placed tightly around tree, causing girdling; *f*, showing attachment of trolley guy wires; *j*, loose loop fastened with clamps and separated from tree by blocks; *e*, cross-section of same; *o*, creosoted oak blocks with groove *x* to support the wire.

but what is termed the "ring construction" system may be used to advantage in many instances, particularly in the suburbs. In this way it is possible to run a line through avenues of fine trees in the country districts without necessitating pruning or disfiguration.

Rights of way for poles on private property back of residences are sometimes secured, and by this means the poles and wires may be removed from the streets, much to the advantage of the trees. But such rights are often difficult to secure, and are not always satisfactory either to the public-service corporations or the owners of the property. The former naturally do not care much for these rights of way unless they are legal and permanent, and the owners in granting permanent rights run a risk of lowering the value of the property. Most of the very high-tension transmission services, however, are at present on private property and seldom interfere with trees. High-tension lines are affected seriously merely by close proximity to trees; therefore these rights of way have to include broad strips of land, which of course is expensive.

On general principles it is not wise to allow wires to be attached to trees, although this is often done. Trolley and electric light wires are frequently guyed to trees, but they are a source of danger, since injury is likely to occur from the crossing of the wires, and lightning discharges occasionally pass from the wires to the tree, causing damage.

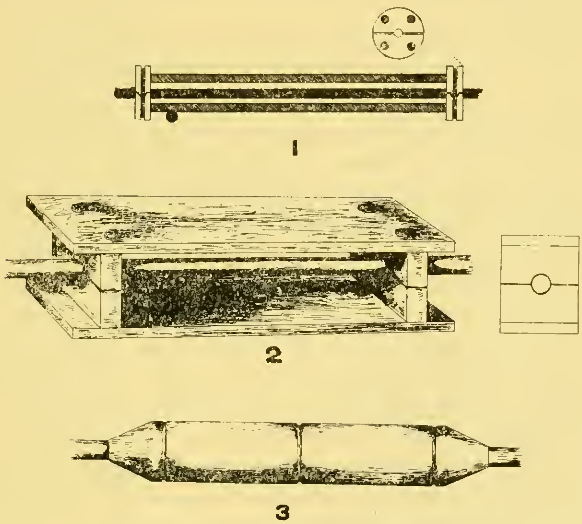

FIG. 14. — Showing different types of guards for electric wires: 1, porcelain dowel guard; 2, porcelain wood guard; 3, wooden sleeve.

It is, however, often better to allow this than to endure the erection of ugly poles; but proper insulation of the wires should be insisted on, although ordinary insulators have little effect on lightning discharges. The lagbolt system in common use for guying wires to trees is not the best method, for sooner or later the wire and bolt become imbedded in the tree and cause injury. Moreover, a direct metal connection with a tree is objectionable, as it has in more than one instance proved. The block system is better, although it may not in all cases be free from objections. In no case should a wire be allowed to pass tightly around a tree, as it will girdle it in time. When live wires come into contact with limbs, some type of insulator should be employed similar to that shown in 1, Fig. 14, of which there are various types, some being quite effective in preventing injury from low-voltage lines. The type shown in Fig. 14, No. 2, is cumbersome and unsightly, but is one of the most effective. The principle of the porcelain and dowel insulator is good, but it has a tendency to slide on the wires and become displaced. If it were provided with larger dowels, and the danger of displacement on the wires done away with, it would prove much more satisfactory.

Wires often accidentally come into contact with trees by the displacement of poles, particularly on curves, where the strain is very great, but much of this injury may be prevented by imbedding the poles in Portland cement. It should be pointed out that the necessity for guying poles to trees may be obviated in this way.

Better methods of handling this vexatious question of wires and shade trees should be forthcoming in the future, and even at present there must be a compromise between the tree warden or city forester and the companies as to the best method of wiring through tree belts and the amount of pruning allowed. Conditions at present favor the corporations, as they are furnishing valuable and necessary facilities for business, etc., and in towns they obtain their franchises and location of poles from the selectmen with little difficulty. The selectmen notify the abutters of any contemplated installations of poles and wires or of changes to occur in the systems, and the abutters are given a hearing. However, they usually wake up to their duty only after the installation of the lines, when the tree warden must assume all responsibility for injury to the trees. He has to choose between two courses, — prevent the pruning or permit it. In either case the companies can erect the poles and install the wires, allowing the wires to burn their way through the trees, although this, of course, often causes trouble to the corporation as well as to the consumer. In case of injury to trees the warden has access to the courts, but most companies are willing to put up with a few moderate fines for the sake of the right of way through a tree belt.

Summary.

Electricity acts as a stimulus to plants. The minimum and optimum current strengths probably differ little in different plants. The maximum current, or that necessary to kill a plant, is quite variable.

Outside of the disfiguration to trees from pruning necessitated by wires, the greatest injury consists in the local burning and often partial destruction of the tree caused by high-tension line wires.

There is practically little or no leakage from wires during dry weather. In wet weather, however, when a film of water is formed on the bark, more or less leakage occurs, and if the insulation is insufficient, grounding takes place and burning, due to "arcing," results.

No authentic cases have been observed by us where the alternating or direct currents as ordinarily employed have killed trees; but instances are known in which the death of trees has taken place when the polarity in electric railway systems have become reversed; *i.e.*, the rail becoming positive and the feed wire negative.

The burning is more pronounced at the positive electrode than at the negative, and when the current is reversed a larger area of tissue is affected. The burning arises from the heating of the film of water on the bark, which destroys the live tissue underneath.

The high resistance offered by trees and plants in general serves as a protection against severe injury from lightning and contact with high-tension line wires.

The least resistance in trees occurs in the vital layer (cambium) and adjacent tissues.

The electrical resistance of trees is influenced materially by temperature and moisture.

The physiological effect of the direct current on vegetable life differs from that of the alternating.

There is evidence to support the idea that a direct current of not sufficient strength to cause burning may electrolize the cell contents and later result in the death of the tree.

Earth discharges during thunder storms are more common than generally supposed, and are known to disfigure and cause the death of trees.

PLATE I.

FIG. 1.—Showing maple tree injured by lightning discharge from trolley guy wire, causing death of limb and laceration of trunk.

FIG. 2.—Showing the destructive effect on the growth of a maple tree of a mass of wires.

PLATE II.

FIG. 4.—Showing injury to young maple tree by linemen's spurs.

FIG. 5.—Showing the effects of strangulation by wires.

PLATE III.

FIG. 6.—Showing disfigurement of trees caused by high-tension alternating current wires.

FIG. 9.—Showing electrolysis of gas pipes. (After A. A. Knudson, "Corrosion of Metals by Electrolysis.")

PLATE IV.

FIG. 7.—Showing deep burning of large limb by high-tension alternating current wire.

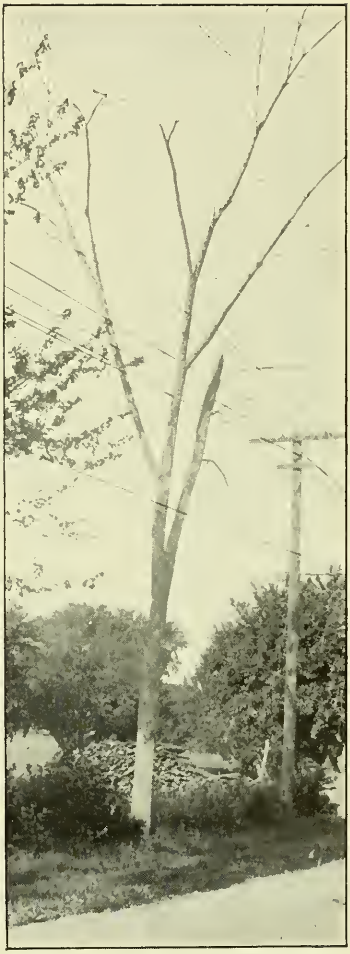

FIG. 8.—Showing elm tree killed by direct current (reversed polarity) from electric railway system. Note effects of burning at the base of the tree.

PLATE V.

FIG. 10. — Showing ridge on elm tree caused by feeble lightning discharge.

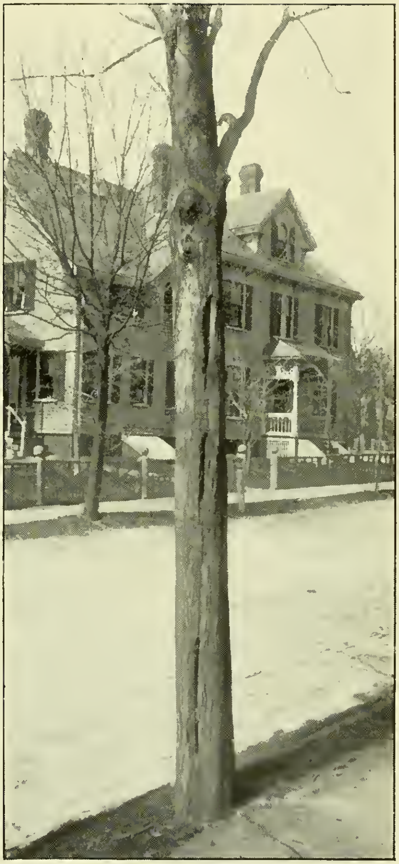

FIG. 12. — Maple showing effects of earth discharges (lightning), causing splitting of the trunk and death of limbs.

THE MARGUERITE FLY OR CHRYSANTHEMUM LEAF MINER.

(*Phytomyza chrysanthemi* Kowarz.) (Order, *Diptera;* Family, *Agromyzidæ.*)

M. T. SMULYAN, B.S.[1]

INTRODUCTION.

The growing of plants under glass is an important industry in Massachusetts, and is becoming more so every year. Among the plants which are of ornamental value, or are raised for their flowers, marguerites or daisies, chrysanthemums and other Compositæ are very generally grown, the two former often on a large scale. It is not at all surprising, then, that complaints are heard on all sides regarding the ravages of the Marguerite Fly, or Chrysanthemum Leaf Miner. Indeed, in many instances, the commercial growing of marguerites and some other Compositæ has been given up on account of this pest.

At the time the writer began the investigation of this troublesome insect it was not generally known that there were one or two florists in the State who possessed a satisfactory method for its control, though such was the fact.

The investigations upon which this paper is based were carried on in the insectary and laboratories of the Department of Entomology of the Massachusetts Agricultural College, Amherst, under the direction of Prof. H. T. Fernald and Dr. G. C. Crampton. The investigations were begun early in February, 1913, and continued to July of the same year, in connection with the marguerite, or cultivated daisy, as a food plant. Some additional data relating to the life history of the insect were collected during the following November. The thanks of the writer are due both to Professor Fernald and Dr. Crampton for their interest in the work, and for a number of valuable suggestions. The writer is also under obligations to Mr. Walker Holden of Andover for furnishing infested marguerites for study, and to the latter again and to Mr. W. R. Nicholson of Framingham for their readiness in answering questions, many of the answers proving very helpful.

[1] Contribution from the entomological laboratory of the Massachusetts Agricultural College. Part of a thesis for Ph.D. degree.

The methods and appliances used in connection with the work are all very simple. The methods are described in the various sections which follow. The habits of the adults were studied very largely with the aid of an ordinary pocket lens while the flies were at large upon the host plants in the insectary. In the study of the other phenomena relating to the adults, cheesecloth bags possessing a certain degree of stiffness were found very useful. In the laboratory, for the study of the various stages, habits of the larva, etc., an ordinary compound microscope and a Zeiss-Greenough binocular were found indispensable.

The outlines of the drawings, except that of the adult, were all made by means of the camera lucida. The photographs were taken by T. W. Nicolet under the direction of the writer.

HISTORY AND DISTRIBUTION.

The Chrysanthemum Leaf Miner, Chrysanthemum Fly, Marguerite Leaf Miner, Marguerite Daisy Fly, or the Marguerite Fly, as the insect is variously called, was first detected in this country, according to Dr. Lintner (Fourth Report on the Injurious and Other Insects of the State of New York, 1888, p. 73) in October, 1886, in the greenhouse of Mr. Chas. A. Dana, near Glen Cove, N. Y. Dr. Lintner writes: "The leaves of some daisies (marguerites) were seen to show some wart-like specks and irregular, whitish, linear markings, and soon afterward to shrivel up and die. Examination for the cause disclosed very small 'worms' working within channels in the interior of the leaves." Some of the infested foliage was sent to Dr. Lintner in Albany the following February. The operations of the insect were first noticed by Mr. Wm. Falconer, head gardener at "Dosoris."

Mr. Falconer reported this discovery independently in the "American Florist," March 15, 1887 (Vol. II., p. 297). "This little pest," writes Mr. Falconer, "made its first appearance here last November." (There is a slight discrepancy between the statements of Dr. Lintner and Mr. Falconer regarding the first appearance of the fly in the greenhouse; according to Dr. Lintner it was October.) "Before then I was not aware of its presence in this country, but since then I find it as abundant in greenhouses at Glen Cove Landing and at Hinsdale as it is here." (Mr. Falconer, like some others at the time, thought the insect a European species.) "I first observed its presence by noticing little wart-like specks and irregular, whitish, line-like markings on the leaves of some of the marguerites, and these traces soon multiplied exceedingly and the much-affected leaves withered up and died. The fly is a small insect and might readily be mistaken for one of the little flies so abundant about fermenting horse manure. When disturbed it 'hops' about rather lazily or flies from one branch to another, but seldom flies away more than a few feet. It lays its eggs singly under the skin of the leaf, the wart-like specks forming over the eggs. In a few days' time the little white grubs are hatched; these are the evil workers. They devour the fleshy substance between the skins of the leaf, eating their way in irregular lines or broad patches, and these are the whitish markings observable on the surface of the leaf. After two weeks of energetic eating it thrusts its head outside of the skin of the leaf and pupates. From the laying of the egg till the perfect insect issues from the chrysalis is within five weeks."

Dr. Lintner (Fourth Report on the Injurious and Other Insects of the State of New York, 1888, p. 76) mentions Queens, Long Island, as another locality where the insect was present at about the same time it was operating at Glen Cove Landing and Hinsdale.

The depredations of the fly seem to have been noticed elsewhere in New York about the same time, infested chrysanthemum leaves having been received from Mr. Charles Anderson of New York by the Department of Agriculture at Washington, Dec. 30, 1886. (Coquillett, Insect Life, VII., 1894–95, p. 399.)

Two weeks later, Jan. 14, 1887, infested marguerite leaves were received by the Department of Agriculture at Washington from Prof. Thomas Meehan of Germantown, Pa.

In 1889 the insect was found mining in the leaves of Japanese chrysanthemums (in the Arnold Arboretum?), near Boston, Mass. (F. J. Jack, Garden and Forest, III., 1890, p. 440), and according to Mr. Jack it had been troublesome in other places in the vicinity of Boston, mining in the leaves of chrysanthemums, eupatoriums and cinerarias in greenhouses. (Lintner, Seventh Report on the Injurious and Other Insects of the State of New York, 1891, pp. 244, 245.)

In 1890 infested marguerite and feverfew leaves were received by the Federal Department of Agriculture from Irvington, N. Y., Danbury, Conn., and Brooklyn, N. Y. (Coquillett, Insect Life, VII., 1894–95, p. 400.)

In February, 1893, infested cineraria leaves were received by Dr. Lintner from the greenhouses of St. Vincent's Male Orphan Asylum, Albany, N. Y. (Tenth Report on the Injurious and Other Insects of the State of New York, 1895, p. 510.)

In April, 1907, Mr. C. W. Johnson of the Boston Museum of Natural History received specimens of the adult fly for identification from Prof. E. D. Sanderson of New Hampshire, indicating that it was causing trouble in that State about that time.

In 1911 it was reported in Connecticut again. (Britton, Eleventh Report of the State Entomologist, 1911, p. 342.)

In 1912 it was discovered mining marguerites in a greenhouse in Helena, Mont. (Cooley, Tenth Annual Report of the State Entomologist, Bull. No. 92, November, 1912, p. 56.)

During the spring and summer of the same year a very serious outbreak occurred in some greenhouses in Milwaukee, Wis., which had imported infested chrysanthemums and marguerites from Boston, Mass. It was also reported from Chicago "and other parts." (Sanders, Journal of Economic Entomology, Vol. V., No. 6, December, 1912, p. 472.)

Since 1899, no data being available previous to that year, at least five complaints have been received from various parts of Massachusetts by Dr. H. T. Fernald, Entomologist for the Massachusetts Agricultural Experiment Station. The last complaint was made in January, 1913, by Mr. Walker Holden of Andover, and led to the investigation of the pest by the writer. Replies to inquiries made during the summer and fall, however, indicate that the pest is generally distributed throughout the eastern part of the State.

FOOD PLANTS.

Falconer, in his account of the insect in the "American Florist," states that while the marguerite (*Chrysanthemum frutescens*) seems to be its favorite food, it does not at all restrict itself to this plant, but attacks every other plant of the family Compositæ within reach. It appeared to Mr. Falconer that it even preferred the double white feverfew (*Chrysanthemum parthenium*) to the marguerite. He mentions *eupatoriums*, *gazanias*, *Helianthus decapetalus* var. *multiflorus*, and *Senecio* (*Cineraria*) *cruentus* as also having been attacked. Dr. Lintner received from the same greenhouse infested leaves of the tansy (*Tanacetum vulgare*) and of three other Composite species which he did not identify. As already stated, the common greenhouse chrysanthemum (*Chrysanthemum indicum*, *C. morifolium* or *C. sinense*) was very early noticed as a food plant. This completes the list of food plants recorded, so far as the writer has observed.

During the writer's investigations, however, adult flies were reared from a number of additional species of plants of the family Compositæ. These plants, though growing in the greenhouse, are not normally greenhouse plants, but had (with the exception of one, — *Helianthus annuus*, the common annual sunflower, which was growing in the greenhouse of the Department of Botany, and was found infested the following fall) simply been allowed to grow, together with a number of other weeds, in the hope that new food plants might perhaps be discovered. These plants are *Solidago nemoralis*, goldenrod; *Ambrosia artemisiifolia*, ragweed; hogweed, etc.; *Taraxacum officinale*, dandelion; *Bidens frondosa*, beggar ticks; *Daucus carota*, wild carrot; *Chrysanthemum leucanthemum*, the common white or ox-eye daisy; and *Antennaria plantaginifolia*, everlasting or ladies' tobacco.[1]

The discovery of the above food plants suggested that the pest could lead an outdoor existence, even in absence of its cultivated food plants, and, surely enough, during the last days of April some dandelions growing at the foot of the greenhouse were found infested.

The flies apparently did not venture from the immediate vicinity of the house. Only the plants at the foot of the house were attacked, and numerous observations which continued into late June failed to disclose

[1] These plants were kindly identified by Mr. Geo. H. Chapman and Prof. A. V. Osmun of the Department of Botany.

others infested. The following December, however, the writer discovered the flies in the greenhouses of the botanical and floricultural departments, somewhat removed from the insectary, where they had been attacking for some time sunflowers, marguerites and cinerarias.

Falconer's observations, to the effect that the insect shows a strong partiality for marguerites, seem to have been correct. Chrysanthemums in close proximity to the marguerites in the insectary were only very slightly attacked. A very strong inclination was manifested for the dandelion, goldenrod, ragweed, and ox-eye daisy, however. These were badly injured and were much preferred to the white marguerites; indeed, after these plants became numerous and large, the white marguerites were almost entirely neglected. The yellow marguerites, on the other hand, remained favorites, and continued to be badly infested.

NAME.

In the earliest published report on this insect by Falconer in the "American Florist," it was designated *Phytomyza affinis* Fallen, the name having been taken from a species which was doing similar injury to plants in Europe, and which now occurs in North America.

Dr. Lintner, however, obtaining specimens of this insect and finding it unknown to him, submitted the adult fly, together with its pupæ and larval mines, to Baron Osten Sacken, who identified it as the European species *Phytomyza lateralis* Fallen. It was thus designated by Dr. Lintner in his report on this insect in his fourth annual report.

Somewhat later, other specimens found mining chrysanthemums and other plants in the vicinity of Boston by Mr. J. G. Jack, and believed by him to be *Phytomyza nigricornis* Macquart, were forwarded by Mr. Jack to Baron Osten Sacken for determination. On examination these were found to be the same as those previously submitted by Dr. Lintner and which were identified as *Phytomyza lateralis* Fallen; but as they did not correspond with *P. lateralis*, Osten Sacken realized the mistake he had made and lost no time in notifying (early in 1890) Dr. Lintner, writing in part, as follows: —

> I am very sorry to acknowledge that I must have misled you in this case by a wrong determination. I do not remember now under what circumstances I committed the blunder and what prevented me from sending the specimens to Kowarz.

The examples from Mr. Jack were then sent by Osten Sacken to Kowarz. Unable to identify the insect with any known European species, Mr. Kowarz described it as a species new to science, and named it *Phytomyza chrysanthemi*. The description, translated by Osten Sacken, was first published in this country in Dr. Lintner's "Seventh Report on the Injurious and Other Insects of the State of New York," 1891, p. 243.

Aldrich in his "Catalogue of North American Diptera" (1905) lists it as *Napomyza chrysanthemi* Kowarz (*Napomyza* originally a subgenus of

Phytomyza, but now raised to generic rank by some writers), but this is clearly an error, as the keys in the literature referred to in the catalogue place the insect in the older genus *Phytomyza*, the posterior cross vein being absent in *chrysanthemi*.

Sanders (Journal of Economic Entomology, Vol. V., No. 6, December, 1912, p. 472) has already referred to the insect by this catalogue name.

INJURIES.

(Plates II. and III., Figs. 9, 10, 12.)

The first indications of the activity of the insect are seen in minute, pale specks, blotch-like, and usually fan-shaped, on both surfaces of the leaves (Fig. 9). As a rule, they are more numerous on the upper side. These specks or blotches are produced by the adult female fly, which pierces the epidermis and destroys the parenchyma beneath by means of her ovipositor, for the purpose of feeding or egg laying.

These blotches, however, do not long retain their original appearance. In a few days, as a result of a reaction on the part of the injured parenchyma, they usually develop into wart-like protuberances or papillæ (Fig. 9); and when the flies are abundant, during a period of great activity, the surfaces of the leaves may be literally covered with the papillæ, or papillæ and blotches together. On the other host plants which were kept under observation in the insectary the papillæ developed less readily, and as a rule, less perfectly.

The real damage, however, is caused by the larva or maggot. Seemingly possessed of a tireless energy and of appetites which never seem to be satisfied, the maggots move slowly along beneath the epidermis (most of the feeding is done immediately beneath the epidermis of the upper surface) of the leaf, devouring the parenchyma in their course, and leaving a whitish and usually irregular path — the external evidence of the mine which lies directly beneath — in their wake, the white color of which contrasts sharply with the green color of the rest of the leaf surface (Fig. 10). The mine widens and becomes more distinct as the larva increases in size. The part of the leaf thus mined (the petiole very often also), or the whole, if it is badly attacked, gradually dries up, and in this withered condition remains clinging to the plant (Fig. 12). Small plants may be killed in a comparatively short time during a period of great activity of the flies.

In reply to some questions of the writer in regard to the resulting injury, Mr. Walker Holden, who kindly furnished the infested marguerites for study, states that "the infestation reduces the number of flowers and weakens the plants to a very great extent." Moreover, he is of the opinion that, because of the reduced vigor of the plants, there is a tendency towards a reduction in the size of the flowers.

Of the plants (feverfews, yellow marguerites, and white marguerites) attacked in Mr. Holden's greenhouse, the yellow marguerites were the most seriously affected — so seriously that he destroyed them. Of the two yellow marguerite plants kept under observation in the insectary, one did not bloom until June (the plants were received early in February), when the flies in the house had decreased and the attack had considerably abated, while the other produced no flowers at all — at least up to July 5, when the writer left Amherst for the summer. Buds in many instances formed, but they dried up after reaching a certain size. The following December the two yellow marguerite plants were dead.

IMPORTANCE OF THE PEST.

The wide distribution of the insect, the large number of commercially grown plants it attacks, the numerous complaints, — many of these reporting serious injury, — all attest and bear testimony to the seriousness of its depredations.

As far back as 1890, Mr. J. H. Ives of Danbury, Conn., writing to Coquillett of the federal division of entomology, stated that he would be compelled to abandon the growing of such plants as marguerites and feverfews, owing to the attack of this pest.

According to Britton (1911) the damage in Connecticut has been so great in some instances that the growers had to abandon the commercial growing of such plants as chrysanthemums, marguerites, feverfews, cinerarias, eupatoriums and tansies.

Sanders (1912), in reporting an outbreak in Wisconsin, states that the growers were facing an entire loss of their flowering plants caused by a complete infestation of the leaves.

Mr. Walker Holden, in reply to a letter of the writer, closes as follows: "I shall be very glad to help out in any way I can to conquer this pest, for it is surely a pest."

Fortunately, no great fears, it seems, need be entertained in regard to the insect as an outdoor pest, it appearing to be essentially an indoor or greenhouse insect. If provided with food, it will remain in the greenhouse all summer, although in reduced numbers. In addition to its being essentially a greenhouse pest, it is apparently also essentially a moderate-temperature insect, seeming to find its most congenial conditions in a temperate and somewhat humid atmosphere. The writer had noticed a considerable falling off in its numbers even before he left Amherst for the summer (first week in July). This could not be explained entirely on the ground that some had left the insectary to take up an outdoor existence, for those that left apparently remained in the vicinity of the insectary, and their numbers could therefore be observed. The hot, sunny, dry atmosphere in the insectary, it seems, is a much better explanation of the decrease. Such an environment may cause itself to be felt in a number of ways. It may diminish the egg-laying powers of the female; it may cause a reduction in the percentage of eggs hatching; it may cause the death of certain larvæ (the writer found both eggs that failed to hatch and dead larvæ in a number of instances in late June), etc. It is quite likely that the numbers of the insect are reduced in a measure in all these ways. The fact that the insect has not been reported as an outdoor pest throughout all these years is very strong additional evidence that it is only a greenhouse pest.

LIFE HISTORY AND HABITS.

The Adult. (Plate I., Figs. 1, 2.)

Description.

The following description, taken from Dr. Lintner's "Seventh Report on the Injurious and Other Insects of the State of New York," 1891, p. 243, is Kowarz's original description of the insect, made from twenty specimens which were submitted to him by Osten Sacken in 1890, and published for the first time in this country in the above report: —

Front and face yellow, occiput gray, antennæ altogether black, tip of the palpi generally dark, oral bristles distinct, genæ narrow, hardly equal to one-third of the height of the eye. Thorax and scutellum uniformly gray, sometimes the former with a pale-yellow lateral stripe in front of the root of the wings; thoracic dorsum usually with four pairs of dorsal macrochetæ, but without the intermediate acrostichal [or inner row of the dorso-central] bristles; seldom a few in the vicinity of the scutellum; scutellum with four macrochetæ on the edge. Wings almost hyaline; veins blackish, yellowish near the root; the costal vein reaches the tip of the third vein only, which tip is rather far distant from the tip of the wing; the first, second, and third veins are distinct, the other longitudinal veins are thin, especially the fourth, which ends in the tip of the wing; the sixth vein is incomplete; the posterior cross vein is wanting; tegulæ and halteres pale yellow. Legs black only the knees pale yellow; sometimes also the trochanters of the fore legs yellow. Abdomen black, but little shining, the ventral sides more or less distinctly pale yellow; the posterior edge of the anterior segments with an exceedingly narrow pale-yellow margin; on the last segment this margin is more distinct. Genitals black, those of the male of moderate size; the ovipositor of the female hardly as long as the last abdominal segment.

The following additional minor observations may be appended: eyes red when insect is alive, black when dead; wings somewhat iridescent; the yellow on the ventral sides of the abdomen gradually narrowing from base to apex. Whereas the abdomen in the male tapers gradually and ends bluntly, that of the female ends somewhat pointedly, the last segment having the shape of a truncated cone. Length of body of male 2 millimeters, female slightly larger; this somewhat larger size of the female is especially marked during the egg-laying period.

According to Kowarz this species bears a close resemblance to *Phytomyza affinis* Fallen, but differs from the latter in the absence of the acrostichal bristles and in the shorter ovipositor.

Habits of the Adult.

In common with many other Diptera or flies, the marguerite flies lack the power of strong and long-sustained flight. They crawl lazily about, or make their way from leaf to leaf and from plant to plant in a skipping or hopping flight, very seldom flying more than a few feet at a time. The periods between flights may be quite long, unless the flies are disturbed, and great portions of these periods may be spent at rest in one place. The males are, as a rule, more active than the females, the latter being also more tame.

Their activity and degree of tameness vary, also, with the time of day, with the degree of sunlight and with the temperature. They are comparatively tame in the early forenoon, late afternoon and on cloudy days. Inactivity and drowsiness, as might be expected, are strongly marked at lower temperatures. Both males and females are tame while mating and after, although the female remains thus for a much longer period.

While inactive in darkness they at once become active when brought into bright artificial light. They have been observed to mate in such light, and as will be seen later, will even oviposit.

Both sexes are strongly negatively geotropic, seeking, as a rule, the highest point of an object or vessel in which they are confined, a trait which was found very useful, and of which full advantage was taken by the writer during the investigations.

Mating.

Newly emerged flies kept in confinement in the laboratory, to determine how soon after emergence mating begins, yielded rather widely variable results; that is, there was a wide variation in the length of time elapsing between emergence and coupling for different individuals. While most of the individuals which were confined together for this purpose were of about the same age, some were of different ages, the age varying with the one or the other sex. These periods between emergence and mating ranged from approximately six to approximately forty hours, and were more or less scattered between the two extremes. Under natural conditions, with the flies free and at large on plants, the results would probably be modified. For instance, it is doubtful if under natural and normal conditions, with both sexes in abundance, individuals would abstain from mating for so long a period after emergence as did some in confinement in the laboratory. On the other hand, the fact that some united about six hours after emergence, would seem to indicate that in some instances, at least, mating takes place very shortly after emergence.

The length of time that couples remain united also varies. In one instance a couple remained attached for three and one-half hours, in another, two and three-quarters hours, and in another two hours. The more usual period, however, seems to be from one-half to one hour. As compared with the same in other Diptera or flies, this is rather short. The "northern cherry fruit flies," for instance, according to J. F. Illingworth, may remain coupled for eighteen and one-half hours. (Bull. No. 325, Cornell University, 1912.)

The male mounts the female, as a rule, when the female is at rest, by grasping her with his anterior legs and pulling himself up on her back.

He usually draws near gradually, by successive stages, stealthily. Quite a time is spent in covering the short distance, often too much it would seem, for very frequently the female will walk off or fly away before he reaches her. Sometimes, however, he will draw near at once, and, after a period of variable length of almost perfect quiet, will mount her in the usual way, or land on her back, apparently, by means of a well-calculated leap or jump. Not infrequently he may endeavor to mount the female while the latter is engaged in piercing the epidermis of the leaf for feeding purposes.

The sight of a couple in copulation excites the male quickly. It is not unusual to see two males upon one female, and as many as four have been observed. In one instance, in confinement, a male was observed trying to mate with a dead female, lying near by, on being shaken off by a couple already united.

That the instinct for mating is very strongly developed in the males was evidenced by their attempts, when confined together by themselves, without previously having had access to females, to mate with each other. In such cases one male would yield to the other just like a female.

When connected, the male rests upon the back of the female, his anterior legs grasping her thorax on top between the bases of the wings; the wings are spread apart just enough to accommodate the male. His intermediate legs grasp the sides of her abdomen about in the middle, or more usually, somewhat posterior to the middle, the posterior legs grasping the sides of the abdomen at some point beyond. The abdomen of the male curves downward and slightly forward to meet the genital opening of the female, and the last abdominal segment of the latter is normally raised somewhat above its usual level, due to the insertion of the copulatory organ of the male.

During copulation the female with the male upon her back stands quietly in one place, apparently, moving only when disturbed or when she is desirous of ridding herself of him. In the latter case, she is usually very restless, moving about continually, and in addition, endeavoring with great energy to kick him off. The male is perfectly quiet, excepting that now and then he may raise himself slightly and shake himself very violently, as if desiring to break loose.

On separating, the male immediately or soon after flies away. The female, on the other hand, remains quietly in place, or she may move to another part of the leaf and then come to rest. Immediately after, or after a short period of inactivity, she begins to protrude and retract her ovipositor in quick succession, repeating this, as a rule, a number of times, at irregular intervals.

She then engages in what seems like a cleaning operation, brushing the apex of her abdomen with her hind legs, and in turn rubbing these legs against each other and against the wings, the two legs against one wing, the wing being held between them, and each one against the wing on its own side. It should be added, however, that the flies will often engage in this operation at other times than soon after mating.

Mating takes place, as a rule, in the forenoon — becoming less frequent towards noon — and during the latter part of the afternoon. Mating between about noon and the latter part of the afternoon is not very common on days of bright sunlight. On cloudy days it continues uninterruptedly.

As has already been intimated, couples isolated on leaves on plants in the laboratory were observed mating in artificial light.

As might be expected, the males are polygamous and the females polyandrous; that is, a male will fertilize more than one female, and a female will accept more than one male. The number of matings during adult life is probably large, and continues, it would seem, throughout the greater part of the same. A female confined with one male at a time within a cheesecloth bag upon a leaf on a plant accepted two males four times in three days, one of the males twice in as many days, and the other twice in one day. In another instance, a couple which had separated at 9.40 A.M. were coupled again at 2.40 P.M. of the same day, although during this second coupling the female was very restless, moving about considerably, as if she was not at all contented to receive him. As regards how long mating continues, there is a record of a female which emerged April 13 receiving a male May 22, forty days after emergence and seven days before her death; in another instance, a female which emerged April 10 was observed mating May 13, thirty-four days after her emergence and six days before her death.

Feeding.

The females, at least, feed during their adult life, the food being the juices of the leaves of the host plants. To this end the epidermis of the leaf is pierced and the parenchyma in contact with it at that point is cut or macerated by means of the tubular ovipositor.

The process forms a prominent feature of the female's activity, and is an interesting one to watch. Having selected the site — she often tests the leaf surface with the ovipositor — and placing herself lengthwise upon the leaf or leaf-lobe, so that her longitudinal axis is parallel with the longitudinal axis of the leaf or leaf-lobe, she flexes the apical portion of her abdomen downward and forward so that it approaches the leaf surface vertically. The epidermis is then pierced, and the ovipositor, which is but slightly exserted while it pierces the epidermis, is inserted into the leaf horizontally. Then, by means of a series of motions of the ovipositor in longitudinal, diagonal, and sometimes transverse directions, involving the alternate protrusion and partial retraction of the ovipositor, and accompanied by a rotary motion of the abdomen, the parenchyma in contact with the epidermis is cut or macerated. The apical portion of the abdomen is, as a rule, angulated somewhat during the latter part of the operation.

Following the withdrawal of the ovipositor, she backs up, and, applying her proboscis to the aperture previously made, feeds on the juices of the tissue thus exposed, protruding and retracting her ovipositor several times while so engaged. Towards the last of the feeding the proboscis is applied intermittently. The blind end of the incision made is almost invariably directed towards the apex of the leaf or leaf-lobe.

The length of time spent in the process varies. A large number of observations showed a variation of from twenty to one hundred and forty seconds for the piercing and cutting operation, although the more usual was from thirty to sixty seconds, and a variation of from six to one hundred and twenty-nine seconds for actual feeding, the more usual period being from about twenty to forty seconds.

The immediate apparent effect of the piercing of the epidermis by the female and her subsequent cutting directly beneath it is a very small, pale and usually fan-shaped blotch with a minute aperture in its periphery at the point where the handle of the fan would be located. This blotch, which measures roughly from $\frac{1}{2}$ to $\frac{3}{4}$ millimeter by $\frac{1}{2}$ to nearly 1 millimeter, but usually $\frac{1}{2}$ by $\frac{3}{4}$ millimeter, represents the area of the epidermis cut away from the parenchyma. Its paleness, which contrasts with the green color of the rest of the leaf surface, is due to the maceration or destruction of the green chlorophyllous tissue beneath, which imparts the green color to the colorless and closely applied overlying epidermis.

As pointed out once before, these blotches, with the exception of a few, do not retain their blotch-like appearance. Reacting to the injury, the leaf tissue at that point is stimulated to new growth, and, growing outwardly, away from the center, gradually undergrows the elastic epidermal area or blotch and raises it above its normal level, forming a wart-like tubercle or papilla with a single perforation at a point in its periphery. (Plate II., Fig. 9.) On the other host plants under observation in the insectary these papillæ formed less readily and less perfectly.

Feeding is done to a greater extent from the upper surface of the leaf.

Do the males feed upon the juices of the leaf tissue of the host plants as do the females?

Lacking the ovipositor with which the females are provided, the males are of course unable to pierce the epidermis of the leaf. In order, therefore, to feed upon the juices of the leaf tissue they must resort to the punctures made by the females. This, it should be said, the writer has not observed them doing. Experimental evidence, however, as will be seen below, though somewhat contradictory, would seem to indicate that they do.

Thus males live longer when confined with females upon leaves on plants which are pierced by the females for feeding purposes than when isolated by themselves, under the same conditions, on leaves which remain entire on account of the inability of the males to pierce them. The length of life of a large number of males isolated by themselves on leaves within cheesecloth bags was from two to five days, although a single individual lived seven days. On the other hand, males confined with females under the same conditions lived from four to thirty days, the greater number living considerably longer than five days.

To determine whether this longer period of life was due to feeding or to possible psychological influence or physiological effects following mating, males were isolated upon leaves upon which females had previously been confined and which leaves had been pierced by them. The males were thus afforded an opportunity to feed without being subjected at the same time to possible influences above mentioned, due to the presence of the females. Again, in order that they might have a condition approximating to that when free and at large upon the plants in the greenhouse — leaves with both old and new scabs — each series of males and females was alternated between the leaves, upon which they were respectively isolated at frequent intervals. Of the 19 males kept under these conditions only 3 lived considerably longer (eleven, twelve and thirteen days, respectively) than those kept by themselves on the unpunctured leaves.

On the other hand, of the 43 males confined with females of various ages in glass jars in absence of all food, the females being replaced daily or every other day, and mating observed in many instances, the usual longevity (if a single individual which lived four days is excepted) was three days.

Oviposition.

The details of the egg-laying process are practically a repetition of those of the feeding process. It differs from the latter process only in one essential particular, viz., the deposition of a single egg in the horizontal incision, in immediate contact with the epidermis of the leaf, just before the ovipositor is withdrawn. The tissue in contact with the epidermis having been sufficiently cut or macerated, the ovipositor is partially retracted for a few seconds, then protruded for a final and last time (often twice), the egg being deposited at the same time. The time spent in piercing and cutting the tissue in oviposition, in the instances observed by the writer, varied from twenty to forty-five seconds, and the subsequent feeding, from five to thirty-eight seconds. Only in a single instance did a female fail to feed after the deposition of the egg. The eggs are, as a rule, deposited from the lower surface of the leaf, and can be seen through the epidermis with the aid of a hand lens when the light is favorable. As a rule, the young leaves at the apex of a branch, or shoot, are not oviposited in, although they may be pierced for feeding purposes. The latter part of the afternoon appears to be a favorite time for oviposition.

Dr. Britton (Eleventh Report of the State Entomologist of Connecticut, 1911, p. 342) states that "the eggs are laid in or on the underside of the leaves." The writer has found only one egg deposited on the surface (lower surface) of the leaf during his investigations, and he regards the phenomenon as abnormal, as the larva, as will be seen below, is unable to rupture the epidermis of the leaf and start a mine, and, when exposed on the surface of the leaf by being taken out of the mine, or by rupturing the epidermis which shields it, soon perishes.

Oviposition in Artificial Light.

While engaged in making an observation one evening on some adults confined upon a leaf within a cheesecloth bag on a plant in the laboratory, the writer noticed a female in the act of piercing the epidermis of the leaf. Whether this was done for the purpose of merely feeding, or for ovipositing, he was unable to say. To determine whether fertilized females would oviposit in artificial light, two fertilized females were isolated in the evening on a leaf within a cheesecloth bag on a plant placed in a darkened room. The leaf on which these females were confined was exposed to a fairly strong light, being about 15 inches from a 32 candle-power Mazda lamp. At this distance the leaf seemed to be — as perceived by the palm of the hand — just out of the higher temperature zone formed by the radiation of the lamp. Also, the leaf was so placed as to receive a uniform amount of light on its two surfaces.

The flies were removed from the leaf early next morning, having been on it for a period of ten hours. On examination it was found that oviposition had taken place. Twenty-four larvæ were subsequently counted.

Oviposition in Absence of Light or Total Darkness.

In this case five females that were caught at large on plants in the insectary in the forenoon (four of these were taken as they disengaged from mating) were isolated in the evening on a leaf within a cheesecloth bag on a plant placed in a dark room. In addition, the portion of the plant bearing that leaf was covered with a black cloth bag impervious to light. The flies were removed early next morning, after being on the leaf for nearly eleven hours. On examination, eggs were found to have been deposited. Eight larvæ hatched.

Assuming that the number of larvæ hatched in this experiment, as well as in the preceding one, represents the number of eggs laid in each, it is at once apparent that the number of eggs laid per female by the five females in absence of light was much smaller than the number laid per female by the two females in artificial light, the proportion being 1.6:12. Also, it should be borne in mind, that as the five females were taken in the morning and were not placed on the leaf until evening, they had neither the opportunity to feed nor to oviposit for a period of about ten hours previous to being placed on the leaf. These facts, in conjunction with their usual inactivity in darkness under normal conditions, leads the writer to believe that under normal and natural conditions oviposition in absence of light does not take place, and that the few eggs laid by the females in the experiment were due in all probability to the abnormal conditions to which these females were subjected previous to their isolation on the leaf.

Again, it is possible that some of the eggs were deposited while the flies were being placed on the leaf by artificial light, although it was endeavored to keep them from doing so by keeping the leaf in constant agitation. At any rate, all the eggs could not have been deposited within that short time.

However, the fact remains that absence of light or total darkness is not necessarily an absolute bar to oviposition.

Oviposition — how soon after Emergence.

To determine how soon after emergence egg-laying begins, virgin females soon after their emergence were confined with males until they mated. Immediately following mating, each female was isolated on leaves on a plant in the laboratory, being shifted from leaf to leaf at regular and short intervals. One of these females laid her first eggs (fertile eggs) between twenty-five and thirty-six hours after emergence and between seventeen and twenty-eight hours after fertilization; another between thirty-one and forty-three hours after emergence and between two and three hours after fertilization; another between thirty-one and thirty-six hours after emergence and between twenty-two and twenty-five hours after fertilization. The rather wide limits are due to the limits of the period during which each female emerged, and which necessarily has to be embraced. It would seem, then, if these three females can be taken as criteria, that the first eggs are deposited on the second day of adult life or the second day after emergence, in the laboratory, at least.

Length of Egg-laying Period.

To learn how long females continue ovipositing, newly emerged virgin females were confined with males within cheesecloth bags on leaves on plants in the laboratory. New males were introduced from time to time to take the place of those dying, the females never being without males for any great length of time. These flies were shifted periodically, daily, or every other day, from one leaf to another, throughout the lifetime of the females. After the flies were removed the leaves were examined with a pocket lens, but the presence of larvæ within the leaves was surest proof that eggs were deposited.

One female, in March and April, which lived for twenty-one days, continued ovipositing to within three days of her death, the last eggs being deposited on the eighteenth day. Another female, in March, which also lived twenty-one days, continued to oviposit to within six days of her death, depositing the last eggs on the fifteenth day. Another one, also in March, which was confined with males upon a plant in a cage in the insectary for the purpose of ascertaining the number of eggs a female deposits during her lifetime, oviposited for the last time, as closely as could be calculated, on the sixteenth day of her adult life. Just when this female died is not known. Still another female, in May (latter part), which lived seventeen days, continued ovipositing to within one day of her death, depositing the last eggs on the sixteenth day.

Number of Eggs laid by a Female.

The above experiments for the determination of the length of the egg-laying period were used also as a means for ascertaining the number of eggs laid by a female during her lifetime.

As the marguerite leaves on which the flies were confined were not very large, and as a large number of eggs was laid during some of the periods during which each female was kept on a single leaf, it was not possible to count with any degree of accuracy the number of eggs laid during that period. Instead of the eggs, therefore, the larvæ were counted. The newly hatched larva, just as soon as it was recorded, was killed by being stabbed with a needle. It was thus prevented from obscuring and masking other larvæ by its mining. In this way, also, the possibility of its being counted more than once was obviated. But even with these precautions — owing to their escaping death — quite a number had to be denominated as doubtful.

The female, in March, which oviposited for sixteen days out of twenty-one which constituted her adult life, produced 141 larvæ. If 28 are subtracted from this number as having possibly been counted twice, she produced only 113. As this female was shifted from leaf to leaf daily, there is a record of the number of eggs laid every day during the entire period. The distribution was as follows: —

$$\begin{array}{cccccccccccccccc} & 2 & 1 & 2 & 1 & 9 & 3 & 5 & 1 & & 2 & & & 2 & & \\ 1- & 10- & 3- & 12- & 8- & 16- & 6- & 14- & 11- & 6- & 8- & 7- & 4- & 4- & 2- & 1 \end{array} = \frac{28}{113}$$

The upper series of figures represents the doubtful ones.

From this record it is seen that on the first day of the egg-laying period only one egg was deposited, and that similarly only one was laid on the last day; that the greatest number for a single day was deposited the sixth day; that there was in a general way a gradual decrease from the eleventh day to the last; that about two-thirds of the entire number were deposited during the first half of the period. Another interesting feature is seen in the alternation in the relative number of eggs laid, or the rise and fall of the numbers laid, from day to day, during the first half of the period.

The female, in March and April, which oviposited for eighteen days out of the twenty-one which constituted her adult life, produced 136 larvæ, but 16 must be counted as doubtful. This number, however, does not represent the total number, as the leaves on which the female was kept from the twelfth day to the seventeenth, inclusive, were accidentally detached from the plant and were lost as far as results were concerned. A daily record is not available in this case.

The female, during the latter part of May, which oviposited for fifteen days out of the seventeen which constituted her adult life, produced 25 larvæ, 5 of which are doubtful, and deposited 76 eggs, larvæ and eggs together totaling from 76 to 81. The eggs deposited after the third day of the oviposition period failed to hatch for some reason. As it was rather difficult to make out the eggs on this particular plant, and made more difficult some days because of poor light, the number of eggs counted in all probability falls short of the actual number laid. The daily record was as follows: —

$$5\text{-}\overset{1}{19}\text{-}\overset{4}{16}\text{-}4\text{-}1\text{-}4\text{-}5\text{-}5\text{-}1\text{-}2\text{-}1\text{-}1\text{-}6\text{-}3\text{-}3 = \frac{5}{76}$$

As in the first case, the upper figures represent the doubtful ones.

This female deposited the greatest number of eggs for a single day the second or third day, and she deposited at least half of the total during the first three days of the oviposition period. In this case, as in the first, the great bulk of the eggs was laid during the first half of the period.

In other cases newly emerged virgin females were confined with males in cylinder jars until they coupled. As soon as they separated, they were isolated on plants, one female on a plant, in cages in the insectary. New males were introduced from time to time to insure fertilization. Of the three females thus confined, however, only one was successfully carried through a complete egg-laying period. In this case the pupæ produced were counted, as it was impossible to count either the eggs or larvæ without allowing the female to escape; the number counted was 132.

Length of Adult Life.

In these experiments, as in some of the others, cheesecloth bags were again made use of, males and females together, and females by themselves, being confined within the bags upon leaves on plants in the laboratory. In all cases, except one in which a male lived as long as a female, the females lived longer than the males, the length of life of the males ranging from four to thirty days, while that of the females ranged from eleven to forty-seven days. In a number of cases the segregated females lived much longer than those confined with males, their length of adult life ranging from eleven to sixty-seven days.

Whether the phenomenon of the longer life of some of the females kept by themselves was merely a coincidence, or whether it was due to their not having the opportunity to mate, the writer is unable to say, in absence of more extensive data.

In absence of food, the greatest longevity — the usual (a single individual lived four days) — was three days.

The Egg. (Plates I. and II., Figs. 3, 5.)

The egg is colorless, somewhat cloudy; smooth; elongate oval, though rarely oval, somewhat broader towards one or the other end, more often towards the posterior, and, as a rule, more bluntly rounded at the anterior end; a compound microscope reveals a gelatinous cap at the anterior end.

over the micropyle. It is somewhat variable in size: a number of measurements taken showed a length of .25 to .33 millimeter and a width of .14 to .17 millimeter. Its length is, as a rule, slightly more than twice its width.

The segmented embryo is easily made out under the compound microscope in an egg somewhat advanced in its period of incubation. In a still older egg the embryo is found to be already provided with its dark chitinous rake or rasping organ, the dark color of which contrasts strongly with the general paleness of the rest of the body. Another feature of such an embryo is its restlessness. Shortly before hatching this restlessness or activity is strongly marked.

Length of Egg Stage.

The period of incubation is dependent upon the temperature at which the eggs are incubated. To determine the length of this period eggs were marked at the time of their deposition within leaves of plants in the insectary, and these were then periodically examined for their hatching. In other instances, egg-laying females were confined within cheesecloth bags for short periods, upon leaves on plants kept in the insectary, and on others kept in the laboratory, and the eggs deposited in them were then examined from time to time, as in the above cases, for their hatching. The eggs incubated in the laboratory, where the temperature was higher, hatched in from two and one-half to three days after they were deposited. In the insectary, however, where the temperature approximated more or less to that at which marguerites are kept, — about 55° at night and about 65° to 70° during the day (it fell somewhat below and rose somewhat above this both at night and during the day),— they hatched in from a little over four and one-half to somewhat over five and one-half days. The great majority, however, hatched in from nearly five to somewhat over five and one-half days. The greater variation in the length of the period in the insectary was probably due to the greater variation in the temperature, — a condition which could not very well be avoided. There is a record of a period of six and one-half days in the case of two eggs. The writer, however, cannot vouch for its correctness. The larva begins feeding immediately after hatching.

THE LARVA. (PLATES I. AND II., FIGS. 4, 6.)

The larva or maggot mining within the leaves is colorless, the greenish-yellow cast which marks the posterior half being imparted by the green and black pellets of leaf tissue or food which in chain or strand like formations are visible through the body wall. In form it is subcylindrical, tapering anteriorly and posteriorly from the region of the fifth and sixth segments, terminating subacutely anteriorly, and truncately posteriorly. When fully developed it measures about 3.5 millimeters in length and .75 millimeter to slightly over in width across its stoutest portion. It is composed of twelve segments. The first segment is very small and appears like a papilla of the much larger second segment, and contains, ventrally, the mouth opening; segments three and four are comparatively short; the five terminal segments are distinctly longer than the five segments immediately anterior to them. Two contiguous subcylindrical caudal spiracles, dark terminally, project backward from the dorsal portion of the apical end of the last segment. These spiracles are connected by sinews and branched, longitudinal, dorso-lateral, tracheal trunks, one on each side of the body, with the two contiguous cephalic spiracles situated dorsally on the posterior portion of the second segment, each caudal spiracle being connected with the cephalic spiracle on its own side. The anal opening is located at the posterior end of the terminal segment, on the ventral aspect. At the anterior end is seen the dark-colored chitinous and forked oral appendage or rasping organ, conspicuous for its dark color.

The rasping organ or rake is composed of two similar halves lying side by side. They are joined at some points in their course, and the interval between them at other points is so small that it is difficult to make them out at those points as distinct pieces. Each half consists of a short, stout anterior piece or head, the anterior margin of which is modified into strong teeth, and of a more slender and elongate posteriorly forked framework to which the toothed head is attached. The upper of the two posterior prongs is somewhat arched and is longer than the straight lower one. The two halves are joined for a short distance in the vicinity of the heads and at the posterior portions of the lower prongs. The heads are but slightly separated. The whole works as a unit.

In the mine the larva lies on one side, moving along by bodily or muscular contractions aided very likely by its rasping organ, — which can be seen with the aid of a lens, swinging quite rapidly in a dorso-ventral plane, — with which it can grasp and attach itself to the leaf tissue. Taken out of the mine, or uncovered within the mine by rupturing the overlying epidermis, it is practically helpless. It seems unable to pierce the epidermis of the leaf and start a new mine, nor does it know how to continue feeding in the opened mine. Feeding is, as a rule, attempted, but the attempts are feeble. Thus exposed, it remains active for some time, but its helplessness in this new environment is plainly apparent; its various motions bespeak but a helpless despair. The bulk of its energy soon spent, its activities gradually lessen and finally cease, death resulting in a few hours — the time depending upon the conditions to which it is exposed — from a loss of bodily moisture. In water it continues to live for a much longer period — one lived for slightly over twenty-four hours.

As will be recalled, the eggs are as a rule placed from the lower surface, immediately above the epidermis. The larvæ on hatching, however, do not remain feeding on the spongy parenchyma. With a few exceptions they soon make their way to the palisade parenchyma immediately below the epidermis of the upper surface, where they continue for the remainder of their larval existence, going down again, as a rule, only when the supply of food in their course has been previously exhausted by a brother miner, or to pupate. They make their way to the palisade parenchyma either by mining over the edge of the leaf or by boring directly through the central portion of the mesophyl. Rarely the newly hatched larva will bore its way through in this fashion almost immediately, leaving no trace of its existence whatsoever on the lower surface.

The writer's curiosity was early aroused by this habit of the larva. Of a number of reasons which at first suggested themselves to account for it, only two were finally retained as being the more likely, viz., light and food. The question to be answered, then, was: Is the larva attracted to the palisade parenchyma because of the more and greater degree of light which that surface received, or because of the better food conditions which the palisade parenchyma affords? As regards the latter part of the question, it is well known that the palisade cells composing the palisade parenchyma are compact or close together, while the cells comprising the spongy parenchyma are separated by comparatively large interspaces.

To determine whether light or food was the influencing factor, a number of simple experiments were undertaken. In one series, the upper surface of leaves which were infested by newly hatched larvæ, which larvæ had not as yet made their way to the palisade parenchyma, were darkened by being painted over with India ink.

To guard against inconclusiveness of the first series, owing to the possibility of the ink penetrating and proving repellent, another series of similarly infested leaves were covered with black paper impervious to light. In other cases similarly infested leaves were so fixed as to cause them to remain in an upright position so that both surfaces received an equal amount of light. In still other instances such leaves were so fixed as to reverse their surfaces, the true lower surfaces being turned up towards the better light, the true upper surfaces being turned so as to receive less light. In a few other cases areas directly in the course of larvæ which were already mining in the palisade parenchyma were darkened for the purpose of determining the behavior of the larvæ when the darkened areas were reached.

As a result of the above experiments it may be said that the influencing factor is food supply. Light, however, did appear to be somewhat of an influencing factor in some instances in the case of young larvæ.

The mining (Fig. 10) as it appears on the surface of the leaves shows no particular design. It appears as straight or irregular lines running transversely or diagonally, but usually in a longitudinal direction, and often in loops. This condition is still further complicated in leaves which are infested by more than one larva. In such cases the mining may be seen in patches, or, as it very often happens, the entire leaf is mined. A favorite course for mining is along the margin of the leaf. Within the mine the course of the larva may be traced by a chain of black pellets of excreta which it leaves in its wake.

The mines, or better, perhaps, the channels, are as a rule within the palisade parenchyma, but they dip down now and then into the spongy parenchyma, and, as it often happens, a large portion of a mine may be wholly in the spongy parenchyma immediately above the epidermis of the lower surface. Often, when the food supply is limited, owing to the size of the leaf, or when there are a number of larvæ within one leaf, the entire mesophyl or fleshy portion of the leaf is devoured.

Length of Larval Life.

The length of the larval period, like that of the egg, varies with the temperature to which it is subjected, and is in all probability modified in addition by the relative abundance of food. Of the number of larvæ kept under observation from the day of their hatching, 122 were successfully followed to the day of their pupation, and are available. Sixty-one, or one-half the total number, were mining in plants which were kept in the insectary and were subjected to a temperature similar to that to which the eggs were subjected. The remaining 61 were subjected to a temperature which was, on the whole, much higher (unfortunately the exact temperature is not available) than that to which the first lot was subjected, the plants which they were infesting being kept in a room adjoining the insectary. Again, those in the insectary were followed during November, and the plants in which they were feeding were inclosed within cheesecloth bags to avoid further infestation. The second lot, on the other hand, were followed during February; and as the plants in which they were feeding were kept in a room which was free of adult flies, they were not covered. In both series the killing of larvæ other than those which were being followed had to be resorted to from time to time in order not to lose track of the others.

TABLE I. — *Length of Larval Life of 61 Larvæ in the Insectary during November, at a Temperature of about 55° at Night and of about 65° to 70° during the Day. (See Temperature in Connection with Length of Egg Stage.)*

Number of Larvæ.	Length of Life (Days).	Number of Larvæ.	Length of Life (Days).
7, ...	11	5, ...	14½
4, ...	11½	4, ...	15
9, ...	12	1, ...	15½
3, ...	12½	3, ...	16
9, ...	13	2, ...	16½
5, ...	13½	1, ...	17
7, ...	14	1, ...	18

It is thus seen that there is quite a variation in the period of growth or development of the larvæ, independently of temperature. Food supply probably accounts for some of this variation.

TABLE II. — *Length of Life of 61 Larvæ in the Room adjoining the Insectary during February, at a Temperature, on the Whole, much Higher than that during November.*

Number of Larvæ.	Length of Life (Days).	Number of Larvæ.	Length of Life (Days).
11,	6	4,	9
23,	7	1,	9½
4,	7½	2,	10
8,	8	2,	11
6,	8½		

A comparison of the two tables will show at once the difference in the lengths of the larval periods of the larvæ of the two lots, due to difference in temperature. It should be noted also that there was almost as great a range of variation in the development of the individuals of this lot as in that of the first.

PUPARIUM AND PUPA. (PLATES II. AND III., FIGS. 7, 8, 11.)

Pupation takes place within the larval mine and inside the last larval skin, the latter thus becoming a puparium. The larva when full grown merely shortens up and becomes inactive. Before becoming inactive, however, it deepens slightly that portion of the mine in which it is to come to rest, forming a more comfortable bed or resting place for itself, as one might say. Having done this, it turns upon its dorsal surface and gradually assumes a state of inactivity, becoming yellowish-white opaque at the same time.

The puparium, at first of the color of the contracting maggot or larva, — pale yellow, — becomes in time dull pale yellow or straw color, or it turns to reddish brown, brown and dark brown, darkening with age. It is easily perceived by the unaided eye through the pale, semitransparent epidermis on either surface of the leaf (Fig. 11). Normally it is completely covered by the epidermis, only the minute cephalic spiracles at the extreme anterior end projecting. The caudal or anal spiracles are completely covered, and are not visible on the surface. Dr. Lintner must have mistaken the cephalic spiracles for the anal, in stating that the latter are "thrust outward" through the epidermis. (Fourth Report on the Injurious and Other Insects of the State of New York, 1888, pp. 74, 75.)

The apparent displacement of the cephalic spiracles (see larva) is brought about by the contraction of the anteriormost ventral larval segments before the larva becomes inactive, drawing along with it, first upward then analward, the anterior dorsal portion of the body. As a consequence, the cephalic spiracles, which in the larva are situated on the posterior portion of the second dorsal segment, assume an anterior ventral position in the puparium.

In shape the puparium may be said to be scaphiform or boat-shaped. In outline it is long oval, and approximates in a general way towards that of the larva, being broadest anterior to the center, and tapering from its stoutest portion anteriorly and posteriorly, terminating acutely anteriorly and somewhat truncately posteriorly. As a rule, the length is twice the width (width across the stoutest portion), although not infrequently the width exceeds half the length. A large number of measurements showed a length of 2.25 to 3 millimeters and a width of 1 millimeter to 1.5 millimeters. The greatest width does not necessarily go with the greatest length. The segments are quite strongly marked, and the spiracles are prominent.

While the puparia are seen through the epidermis (Fig. 11) on either surface of the leaf, by far the greater number occur near the lower surface, the proportion being about 2:1; that is to say, pupation takes place more often immediately above the epidermis of the lower surface of the leaf than immediately below the epidermis of the upper surface, the larvæ when about full grown making their way towards the lower surface for that purpose by eating their way through the central portion of the mesophyl. The mining is continued, as a rule, for a greater or lesser distance, after they have eaten their way through.

The puparial content, at first a semiliquid, whitish mass which clings to the wall of the puparium, gradually hardens, through the loss of its fluids, into a white mass distinct from the puparial wall. This mass then gradually differentiates into the pupa proper, which shows the three primary regions — head, thorax and abdomen — of the adult insect, and the rudimentary legs and wings or wing buds. The pupa proper is formed within two and one-half days after pupation at a temperature of about 60° at night and 70° and over during the day, — temperatures slightly higher than those at which marguerites and low-temperature loving plants of its kind are usually kept. It is quite probable that at those lower temperatures the results would be slightly modified. The pupa proper is cream-white in color; the legs are folded on the ventral surface; the wing buds are pressed closely to the sides of the body, their apical portions inclining ventrally.

Length of Pupal Life.

The length of the pupal period, like that of the egg and larva, varies with the temperature, as will be seen by the tables that follow. In all, the periods of 197 are available. One hundred and thirty-four of these developed in plants in the insectary during November, and were subjected to a temperature similar to that to which the eggs and larvæ were subjected. In fact, the greater number of this lot were the pupæ of the larvæ which were followed in the insectary for the purpose of determining the length of the larval period. The remaining 63 developed during the last days of February and the first part of March, and, like their larvæ, in the room adjoining the insectary, where the temperature was markedly higher than in the insectary.

TABLE III. — *Length of the Pupal Period of 134 Pupæ which developed in the Insectary during November, at a Temperature of about 55° at Night and of about 65° to 70° during the Day. (See Temperature in Connection with Length of Egg Stage.)*

NUMBER OF PUPÆ.	Length of Pupal Period (Days).	NUMBER OF PUPÆ.	Length of Pupal Period (Days).
2, ...	12	15, ...	14½
2, ...	12½	20, ...	15
27, ...	13	2, ...	15½
18, ...	13½	1, ...	16
47, ...	14		

It is thus seen that the length of the pupal period also varies independently of the temperature. The variation, however, it should be noted, is less than among the larvæ, as might be expected, especially among the larvæ which, like the pupæ, developed in the insectary, and with which they should more properly be compared. It should also be noted that a period of from thirteen to fifteen days, inclusive, embraces the great majority, indeed, almost all.

TABLE IV. — *Length of the Pupal Period of 63 Pupæ in the Room adjoining the Insectary, during February and March, at a Temperature, on the Whole, much Higher than that in the Insectary during November.*

NUMBER OF PUPÆ.	Length of Pupal Period (Days).	NUMBER OF PUPÆ.	Length of Pupal Period (Days).
7, ...	8	26, ...	10
1, ...	8½	1, ...	10½
19, ...	9	3, ...	11
3, ...	9½	3, ...	12

A comparison of the two tables will show at once the difference in the lengths of the pupal periods of the two lots of pupæ, due to the difference in temperature. Of interest, also, is the fact that the range of variation in the two lots was the same.

The newly emerged perfect female may be described as follows: head, pale yellow, with a broad central longitudinal black band on the occiput: antennæ, black; thorax, grayish; macrochetæ, black; wings, gray, pale at base, unspread; legs, black, with pale-yellow markings on femora and tibiæ; abdomen, pale yellow, dorsally and ventrally, with darker transverse, broad bands, one on each segment; setæ, black; terminal segment, black.

Length of Life Cycle.

The length of a generation varies, owing to the variability of the stages constituting it. The mean or average length of a life cycle, however, may be obtained by combining the mean or average length of each stage.

The average lengths of the periods constituting the life cycle during November, at a temperature at which marguerites are usually kept (see temperature in connection with length of egg stage), are as follows: —

	Days.
Time elapsing between emergence of adult and oviposition,	1½
Length of egg stage,	5
Length of larval stage,	13
Length of pupal stage,	14
Average length of one generation,	33½

Number of Generations in the House.

Knowing the length of a generation, we can calculate the approximate number of overlapping generations or broods which occur in the house from the setting in of the cooler season, when the flies make their first appearance in the house, or when they reappear, or appear in greater numbers, to about Easter, when most of the marguerites are sold out, or to the end of May, in cases where the plants are grown for their bloom. Thus there are at least four complete broods for the period between November 1 and April 1, and at least six complete broods for the period between November 1 and June 1, for a life cycle of thirty-three and one-half days. Owing to the higher temperature during April and May there may be an additional generation, or partial generation, for the period between November 1 and June 1.

Hibernation.

Is the insect able in some one of its stages, say pupa, to pass the winter out of doors? This question is suggested by a letter from Mr. Walker Holden. According to this letter the marguerites and feverfews in Mr. Holden's greenhouse were badly infested by the insect during the winter of 1911. The following spring these plants, as was the practice, were removed from the house to the garden for the summer, and towards fall furnished the cuttings for a new crop. That fall and winter (1911–12), however, there were no signs of the insect in the greenhouse. In the spring the house was again cleared, and the plants, apparently perfectly clean, removed to the garden. In late summer, however, Mr. Holden found the plants infested, and during the following fall and winter (1912–13) the insect was again present in troublesome numbers in his greenhouse.

How is the absence of the fly during the fall of 1911 and winter of 1912 to be accounted for? As there are no other greenhouses in Mr. Holden's vicinity, it could not have passed the winter actively in a neighboring greenhouse. Unless, then, as is possible, it passed the winter in some near-by dwelling house, where some one of its food plants was kept for ornamental purposes, as occasionally happens, hibernation is the only rational explanation that remains.

CONTROL.

Picking of Leaves.

Until recently the picking and destruction of the infested leaves was the only means known for the control of this insect. This method, however, aside from other disadvantages, has not proven effective in all cases. Mr. Walker Holden has had fairly good success with it in the case of white marguerites, but it was utterly ineffective in the case of yellow marguerites, and it rendered the feverfews unsalable. It is quite probable, also, that he would have experienced more difficulty in connection with the white marguerites had he not had in the house at the same time yellow marguerites and feverfews, of which plants the flies are very fond. But aside from the consideration of effectiveness, it is obvious that as a means of control the method is by itself unsatisfactory in cases where plants are grown in quantity and time is valuable. Moreover, the loss of leaves is not to the advantage of the plant.

Spraying.

"Black Leaf 40."

It was the intention of the writer to discover, in connection with his other studies of the pest, a more effective method of control. But before the experiments along these lines were begun, a note entitled "A Remedy for Chrysanthemum Leaf Miner," in the "Journal of Economic Entomology" for December, 1912, by J. G. Sanders of the College of Agriculture, Madison, Wis., came to his notice. In this note Mr. Sanders says in part, as follows: —

> While experimenting with contact insectides for their control, the nicotine solutions, especially "Black Leaf 40," used as a spray with or without whale-oil soap solution, proved a complete and satisfactory control. One part of nicotine in 400 parts of water killed the eggs and larvæ readily, as well as the newly formed pupæ. The pupæ of all ages were killed with $\frac{1}{200}$ nicotine solution.

Mr. Sanders having discovered an effective remedy, the writer thought it superfluous to experiment further along original lines; nor, again, did the time available make it convenient for him to do so. His own experiments, therefore, were designed merely to test Mr. Sanders's results. A solution of 1 part of "Black Leaf 40" in 400 parts of water killed the eggs and the larvæ readily, as Mr. Sanders has pointed out, and a large proportion of the newly formed pupæ. A solution of 1 part of "Black Leaf 40" in 200 parts of water killed a large proportion of the older pupæ. The addition of whale-oil soap did not seem to give any better results.

The "Black Leaf 40," which is a concentrated solution of nicotine sulfate, containing 40 per cent. active nicotine, is manufactured by the Kentucky Tobacco Product Company, Louisville, Ky. It is sold in ½, 2½ and 10½ pound cans, and may be obtained direct from the manufacturers, if it cannot be obtained from a near-by dealer.

"Nico-Fume" Liquid.

Mr. W. R. Nicholson of Framingham was referred to the writer, by Prof. E. A. White of the Department of Floriculture, as one who in all probability was in a position to furnish information regarding the pest. The writer took the opportunity soon after to consult Mr. Nicholson. According to Mr. Nicholson, who grows marguerites on a large scale, the insect was very troublesome in his houses a few years ago. While experimenting with various methods and materials in an effort to control it he tried "Nico-Fume" Liquid as a spray, and found it effective. He has experienced little or no trouble from the insect since he has been systematically using this liquid.

Mr. Nicholson dilutes the "Nico-Fume" in water from about 430 to 450 times, using a cupful — a cup which the manufacturers provide — to 3 gallons of water, and sprays regularly once a week. He begins spraying even before there are any indications of the presence of the insect, preferring to get the start on them rather than have the insect get the start on him. He sprays not only against the Marguerite Leaf Miner with the material at this strength but also, his other plants as well, against aphids. In fact, he is using it as general spray more against aphids and other soft-bodied insects than against the Marguerite Miner, which is of little or no consequence in his houses now. Mr. Nicholson has found no occasion to add soap to the solution.

"Nico-Fume" Liquid, like "Black Leaf 40," is a nicotine solution containing 40 per cent. active nicotine, and is prepared by the same manufacturers. It may also be obtained in the same way. It is sold in ¼ pint, pint, ½ gallon, and gallon cans.

"Nicoticide."

Mr. Nicholson has also used "Nicoticide" at the same strength and in the same way as the "Nico-Fume" Liquid, with equally good results.

"Nicoticide," like the "Black Leaf 40" and the "Nico-Fume" Liquid, is a nicotine solution. It is manufactured by the P. F. Palethrope Company, Owensboro, Ky. It may be had in ounce, ½ pint, pint, and gallon cans.

Relative Cost of the Spraying Materials.

An absolute comparison of the prices of the three spraying materials is not possible for the reason that they are not all sold in similar quantities. A fairly good idea of the relative cost of the "Nico-Fume" Liquid and the "Black Leaf 40," however, may be had from the figures which follow, which indicate the cost per ounce of these materials in each of the quantities in which they are on the market.

"Black Leaf 40."

One ounce in ½ pound costs 10.62 cents.
One ounce in 2½ pounds costs 8.12 cents.
One ounce in 10½ pounds costs 7.44 cents.

"Nico-Fume" Liquid.

One ounce in ½ pint costs 11.76 cents.
One ounce in 1 pint costs 8.82 cents.
One ounce in ½ gallon costs 8.08 cents.
One ounce in 1 gallon costs 7.72 cents.

It is thus seen that, on the whole, the "Black Leaf 40" is slightly cheaper per ounce than the "Nico-Fume" Liquid. The "Nico-Fume" Liquid, however, possesses a possible advantage in that it may possibly be used at a slightly lower strength, Mr. Nicholson using it at the rate of 1 part to about from 430 to 450 parts of water, while from his own experiments with "Black Leaf 40" the writer prefers a $\frac{1}{400}$ solution of the latter to that of a $\frac{1}{450}$ solution. It is quite probable, however, that where spraying will be practiced regularly, as is Mr. Nicholson's practice, the "Black Leaf 40," used at the same strength as the "Nico-Fume" Liquid, may prove just as efficient as the "Nico-Fume."

The tables also show very clearly the advantage of buying either material in the larger quantities.

"Nicoticide" as a spray is entirely too expensive as compared with "Black Leaf 40" and "Nico-Fume" Liquid. It costs $1 more per pint, $3 more per ½ gallon, and $4.50 more per gallon than the "Nico-Fume" Liquid, and one pays 17.5 cents per ounce when buying it in ¼ of a pound quantities.

Conclusions and Recommendations.

It is the opinion of the writer that in a general way the method of combating the Marguerite Miner followed by Mr. Nicholson (see "Nico-Fume" Liquid) might be used by others, certainly by large growers of marguerites and those other plants which the insect attacks. The method has proved itself both effective and economical in the hands of a practical and successful florist, and it has stood the test for several years. However, if one has never been troubled by this insect, and if his practice is to fumigate rather than spray against aphids, spraying should begin with the first signs of the operations of the insect. The second application may well follow one week later, as it is highly desirable that the insect be checked to as great a degree as possible at its very start. The spraying should then be continued regularly every eleven or twelve days. A longer interval than twelve days is not advisable, as it is more difficult to kill nearly full-grown or full-grown larvæ, and pupæ are still more difficult. In spring, when it becomes warmer in the house, — or at any time if the plants are grown at a higher temperature than usual, — the sprayings will probably have to come a little more often. Should one succeed in exterminating the insect, spraying might be discontinued after cold weather has set in, for then the danger of the insect's coming into the house is past. With the coming of spring, however, one's vigilance should be renewed, for if the insect is able to pass the winter outside of the greenhouse in a dormant state, that is, to hibernate, there is a possibility, it may get into the house when it becomes active again. If "Black Leaf 40" instead of "Nico-Fume" Liquid is used, it should, at first at least, be used at the $\frac{1}{400}$ strength. Later, especially if one should spray regularly, 1 part to about from 430 to 450 parts of water, at which strength Mr. Nicholson uses the "Nico-Fume" Liquid, might very likely prove effective.

The importance of thorough spraying cannot be overemphasized, as the insect multiplies very rapidly under normal conditions. Both surfaces of the leaf should be entirely and uniformly covered, as the eggs, larvæ and pupæ may occur in any part of the leaf. Special pains should be taken to hit the lower surfaces of the leaves, as from the lower surfaces will be reached the majority of the eggs and newly hatched larvæ — which will thus be cut off at the very beginning of their career of mischief — and full-grown larvæ and therefore pupæ. As the solution must penetrate into the tissues to do its work, it is important also that it adhere well to the leaves. A nozzle giving a fine spray should therefore be used. Should difficulty for some reason or other be experienced in this respect, the addition of soap might be advisable, — whale-oil soap or good laundry soap, at the rate of 1 pound to about 30 gallons of water. The soap increases the adhesiveness of the spray solution through its own adhesive character, and by lessening the formation of drops the last property insures a more even and uniform distribution of the solution on the leaf surface as well.

The soap should be dissolved in water before the "Black Leaf 40" or "Nico-Fume" Liquid is added — the soap cut in thin slices will easily dissolve in some boiling water. After adding, the solution should be stirred thoroughly to obtain uniformity. More material than is needed for one application should not be prepared; in other words, the materials should be mixed shortly before applying.

Natural Enemies.

Spiders.

The various spiders occurring in the greenhouse, by preying upon the adult flies, capturing them directly, and indirectly by enmeshing them in their webs, are of aid to the florist in that they reduce the numbers of the flies. Especially serviceable seems to be *Salticus senicus* Clerk (identified by Mr. J. H. Emerton of Boston), a gray, brownish, and white form, about one-fourth of an inch long, common in and outside of houses all over North America. The front of its head around and above the eyes is white; there is a white band across the anterior end of the abdomen, and two or three oblique white bands on the sides. In some cases a longitudinal white band passes down the middle of the abdomen. This spider is a plant crawler, and the writer has observed individuals again and again on the marguerite plants, preying upon the adult flies.

According to Mr. Whiting of the Department of Floriculture this spider is very valuable in greenhouses in general, preying extensively on the various aphids, on the Rose Leaf-roller (*Archips rosaceana* Harris), extracting the larva from out of the rolled leaf, and on other injurious forms.

Insect Parasites.

As far as the writer knows, no definite insect parasite of the Marguerite Fly has as yet been reported. The late Mr. D. W. Coquillett, however, was of the opinion that such a parasite exists. Referring (Insect Life, VII., 1894–95, p. 400) to some marguerite leaves which he received from the greenhouses of Mr. James Read of Irvington, N. Y., Feb. 28, 1890, from which adults of the Marguerite Miner were reared, he adds: —

> Quite a large series of chalcidid flies belonging to the genus *Chrysocharis* were also bred, but as the other members of this genus are almost without exception parasitic upon other chalcidid or Ichneumon flies, it is quite certain that the present specimens did not prey upon the leaf miners. Their presence, however, is indicative of the very important fact that these miners have an enemy to contend with in the form of a small four-winged fly that has thus far escaped detection.

SUMMARY OF RESULTS.

History and Distribution.

The Marguerite Fly, or Chrysanthemum Leaf Miner is, as far as known, a native insect. It was first reported from a greenhouse near Glen Cove, N. Y., in the fall of 1886. It has since been found in many other localities. At the present time it is definitely known to occur in the following States: New Hampshire, Massachusetts, Connecticut, New York, Pennsylvania, Illinois, Wisconsin and Montana. It is doubtless present in other States.

Host Plants.

The food plants of this insect are apparently restricted to the family Compositæ. Of the cultivated plants, marguerites and feverfews seem to be the favorites. It is also known to attack eupatoriums, gazanias, helianthus, cinerarias, tansies, chrysanthemums, goldenrod, ragweed, dandelions, beggar-ticks, wild carrot, the common white or ox-eye daisy, and everlasting, or ladies' tobacco. It is essentially a greenhouse pest.

Injury and Seriousness of the Pest.

The injury is caused by the larvæ or maggots mining within the leaves, and living upon the mesophyl or fleshy portion of the same. The mining is seen on the surfaces of the leaves as irregular, whitish lines or patches, the latter often extending to take in the whole surface, and causes the death of part or the whole leaf. The activity of the larva or maggot results in a serious interference with normal growth, in checking flowering or in the reduction of the number of flowers normally produced, and in a reduction in the size of the flowers. Small plants may be killed in a comparatively short time if exposed continually to attack. The depredations of the insect are often very serious. In many instances the commercial growing of marguerites and other Compositæ have been given up on account of it.

Life History and Habits.

The adult insect is a small, grayish fly, only 2 millimeters, or $\frac{1}{12}$ of an inch, long, with a comparatively broad yellow stripe or band on each side of the abdomen, and may be seen resting, or crawling lazily about, or making its way from plant to plant in a skipping or hopping flight. The female fly, as a rule, lives longer than the male. Females confined with males upon leaves on plants in the laboratory lived as long as a month and a half. One female may lay between 125 and somewhat over 150 eggs during her lifetime. The eggs are laid singly in horizontal incisions made by the ovipositor, between the parenchyma, or flesh, and epidermis, or skin, of the leaf, — principally between the parenchyma and epidermis of the lower surface. Similar incisions are made, but mostly between the parenchyma and epidermis of the upper surface, for purposes of feeding on the juices of the leaf. The eggs hatch in from slightly over four and a half to somewhat over five and a half days. The larvæ do most of their feeding immediately beneath the epidermis of the upper surface of the leaf, owing to the better food conditions afforded by the palisade parenchyma, and may feed as long as seventeen and eighteen days. Pupation takes place within the larval mine, and more often in those immediately above the epidermis of the lower surface of the leaf. The pupa stage lasts, as a rule, from thirteen to fifteen days, inclusive. The mean or average length of a complete life cycle or generation is about thirty-three and one-half days. The lengths of the different stages vary also with the temperature to which they are subjected. The above periods are for a temperature at which marguerites are usually grown. (See temperature in connection with length of egg stage.)

Control.

The insect may be controlled by spraying with the nicotine solutions "Black Leaf 40," "Nico-Fume" Liquid and "Nicoticide," diluted from 400 to 450 times in water, and applied at intervals of eleven or twelve days, or somewhat oftener if the temperature in the greenhouse is higher than that at which marguerites are usually kept. The picking of leaves, it would seem, is in most cases neither adequate nor satisfactory.

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EXPLANATION OF PLATES

PLATE I.

FIG. 1. — Dorsal view of adult female fly. Greatly enlarged.

FIG. 2. — Wing of adult fly. Greatly enlarged. 1–6, veins; cos, costal vein; ant. c. v., anterior cross vein.

FIG. 3. — Egg showing contents and gelatinous cap at anterior end. Greatly enlarged.

FIG. 4. — Side view of the anterior and posterior portions of the larva or maggot. Greatly enlarged. fd. or., feeding organ or rake; sp., spiracle; tr., tracheal trunk.

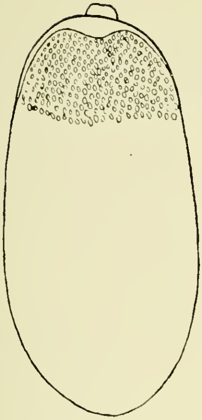

Fig. 3

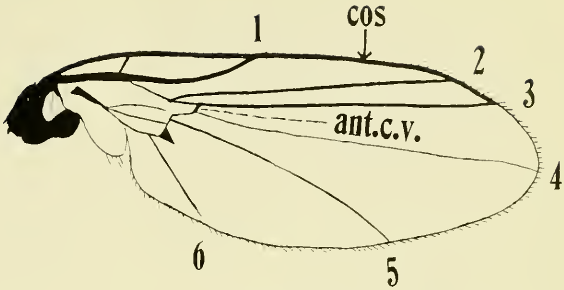

Fig. 2

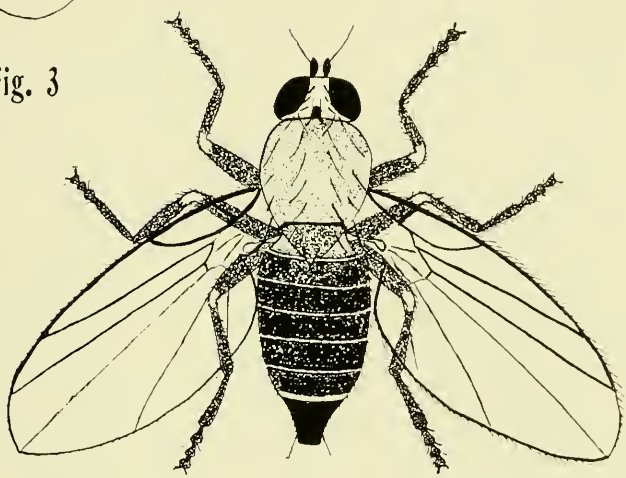

Fig. 1

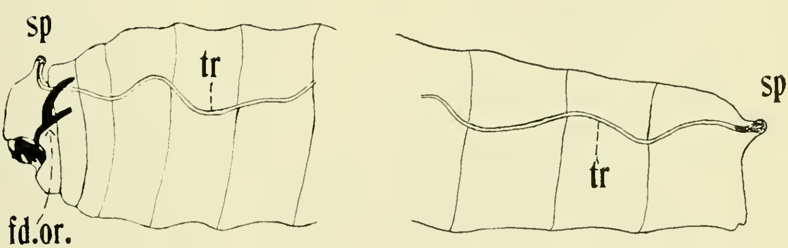

Fig. 4

PLATE II.

Fig. 5. — Egg. Enlarged about twenty-five times.

Fig. 6. — Side view of larva or maggot. Enlarged about nine times.

Fig. 7. — Puparia. Enlarged about twelve and one-half times.

Fig. 8. — Ventral, and latero-ventral view of pupæ. Enlarged about twelve and one-half times.

Fig. 9. — Leaf showing blotches and papillæ produced by the female fly. Enlarged about one and one-half times.

Fig. 10. — Leaf showing the work of the larva or maggot. Natural size.

Fig. 5

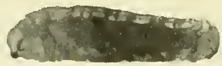

Fig. 6

Fig. 7

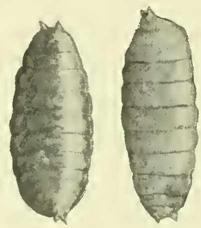

Fig. 8

Fig. 9

Fig. 10

PLATE III.

Fig. 11. — Leaf with pupæ beneath epidermis. Enlarged about three times.

Fig. 12. — A white marguerite plant badly attacked; the dried-up leaves clinging to the plant.

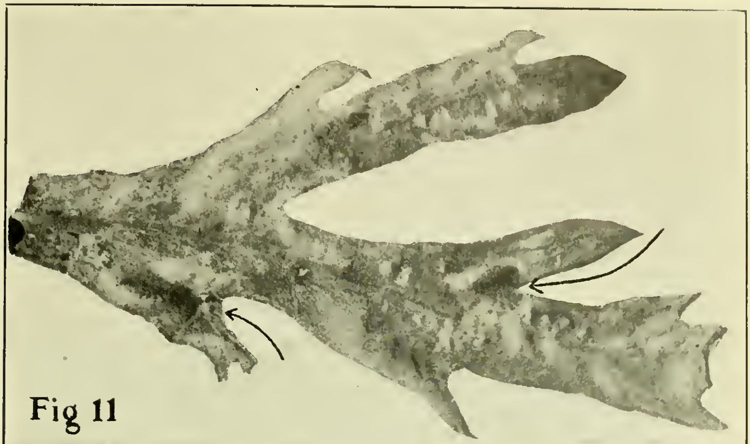

Fig 11

Fig.12

THE COMPOSITION, DIGESTIBILITY AND FEEDING VALUE OF MOLASSINE MEAL, COTTONSEED MEAL AND HULLS, COCOA SHELLS, GRAIN SCREENINGS, FLAX SHIVES, MELLEN'S FOOD REFUSE, AND POSTUM CEREAL RESIDUE (CXX FEED).

J. B. LINDSEY AND P. H. SMITH.

1. MOLASSINE MEAL.

The Molassine meal offered in Massachusetts is an English product [1] composed of substantially 70 to 75 per cent. of cane or beet molasses and 25 to 30 per cent. of sphagnum moss; the latter, as time passes, decays and forms peat. The moss used in Molassine meal, according to the manufacturers, comes from the upper layers of large peat bogs in Yorkshire, Eng., and is probably more or less humified. It is doubtful if the moss has any particular nutritive properties; hence, the *nutritive value* of the feed consists in the amount of molasses present.[2]

Molassine meal is quite dark in color, rather bulky, somewhat moist and slightly sticky, but is in good merchantable condition and appears to keep well.

(1) *Composition of Molassine Meal.*

Analyses made at the experiment station show it to have the following approximate composition: —

	Per Cent.
Water,	18.43
Ash,	7.52
Crude protein,	9.32
Crude fiber,	6.75
Nitrogen-free extract,	57.51
Fat,	.47
	100.00

[1] A product similar to Molassine meal was first made in Germany, where it was patented under the number 79932; it is there known as *Torf-Melasse.* It is also made in France, and known as *Tourbe-Melassée.* Its use in these countries is quite general, particularly as a partial feed for horses.

[2] Kellner and Pfeiffer have shown that peat is without nutritive value.

The presence of so much ash is due to the relatively large amount of molasses. The crude protein is largely in the amino form, and is of doubtful value for flesh and milk production; the extract matter is composed largely of sugar and allied substances; the crude fat or ether extract is of no particular account. A test for potash showed the presence of 4.50 per cent., about the same amount as found in cane molasses.

(2) *Digestibility of Molassine Meal.*

Five trials were made with three different sheep, using 600 grams of hay and 200 grams of Molassine meal in two cases, and 550 grams of hay and 200 grams of the meal in one case. This combination was found to give a rather wide nutritive ratio, so two more trials were made, feeding 550 grams of hay, 150 grams of gluten feed and 200 grams of Molassine meal. The results secured with each sheep, and the average, follow: —

Digestion Coefficients for Molassine Meal.

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Nutritive[1] Ratio.
I.,[2]	59.47	65.31	27.19	14.61	71.30	11.34	1:11.50
V.,[3]	58.54	78.47	58.10	-	70.84	72.13	1: 6.17
V.,[2]	66.60	86.95	32.51	25.00	75.32	-	1:10.03
VI.,[3]	64.44	87.85	66.33	-	70.91	63.11	1: 6.13
VI.,[2]	60.86	78.83	24.55	-	71.12	-	1:10.15
Average,	61.98	79.48	41.74	-	71.90	-	-
Cane molasses for comparison.	78.30	54.85	33.34	-	88.84	-	-

[1] Total ration. [2] Fed with English hay. [3] Fed with English hay and gluten feed.

The results show that the Molassine meal has about the same degree of total digestibility as wheat bran. The ash has a high, and the extract matter a fair degree of digestibility. The fiber was poorly utilized; in some instances none was digested. Where Molassine meal and hay were fed the digestibility of the crude protein was low, due in part to the relatively small amount of nitrogen in the ration in proportion to the metabolic by-products. Where gluten feed was added to the ration the digestibility of the protein was considerably higher. The Molassine meal is some 20 per cent. less digestible than cane molasses (proportion of 62 to 78), due to the presence of the sphagnum moss. Applying the digestion coefficients to the analysis of Molassine, one secures the following number of pounds of digestible organic matter in 100 pounds, and by multiplying by 20, the amount in 1 ton: —

Composition and Digestibility of Molassine Meal.

	Composition (Pounds in 100).	Percentage digestible.	Pounds digestible in 100.	Pounds digestible in 1 Ton.
Protein,	9.32	41.7	3.89	77.80
Fiber,	6.75	–[1]	–[1]	–[1]
Extract matter,	57.51	71.9	41.35	827.00
Fat,	.47	–[1]	–[1]	–[1]
Total,	–	–	45.24	904.80

[1] Not determined on account of the unsatisfactory coefficients obtained. Its omission, however, makes little difference in the totals.

The Molassine meal, with 18.43 per cent. of water, is shown to contain 905 pounds of digestible organic matter in 1 ton, as against 1,377 pounds in a ton of corn meal with this same amount of water, and against 1,524 pounds in kiln dried corn meal with 11 per cent. of water. In the former case the Molassine meal would have 66 per cent. of the nutritive value of corn meal, or in the latter case 59 per cent. Viewed solely from the standpoint of nutrition it can safely be said that the material is noticeably inferior to corn or to the other cereals.

(3) *Feeding Experiment with Dairy Cows, 1913.*

This experiment was undertaken for the purpose of comparing the relative value and feeding effect of Molassine meal as compared with corn meal; *i.e.*, to note if the animals would eat the Molassine meal readily, and also to observe its effect upon the general condition of the animal and upon the amount of milk produced.

Six cows were fed by the reversal method in periods of three weeks' duration. Hay, wheat bran and cottonseed meal constituted the basal ration, to which were added definite amounts of either Molassine or corn meal.

TABLE I. — *History of the Cows.*

NAME.	Breed.	Age (Years).	Last Calf dropped.	Served.	Milk Yield (Pounds), Beginning of Trial.
Amy,	Pure Jersey,	5	Dec. 21, 1912	Mar. 4, 1913	24
Betty,	Grade Jersey,	8	Oct. 30, 1912	Feb. 11, 1913	21
Samantha II.,	Grade Holstein,	4	Feb. 13, 1913	– –	35
Fancy II.,	Grade Jersey,	5	Sept. 14, 1912	Jan. 28, 1913	21
Cecile,	Pure Jersey,	7	Dec. 18, 1912	Mar. 9, 1913	21
White,	Grade Holstein,	4	Mar. 12, 1913	– –	43

TABLE II. — *Duration of Experiment, 1913.*

DATES.	Corn Meal Ration.	Molassine Meal Ration.
May 2–May 23,	Fancy II., Cecile, White,	Amy, Betty, Samantha II.
June 6–June 27,	Amy, Betty, Samantha II.,	Fancy II., Cecile,[1] White.

[1] June 13 to July 4 for Cecile.

Twenty-two days elapsed between the two parts of the experiment in case of Cecile, as she could not be induced to eat the full ration of Molassine (4 pounds), and it was finally found necessary to reduce the amount to 3 pounds and add 1 pound of corn meal. The intermediate period for the other cows was fourteen days.

Care and Feeding of Animals. — They were kept in roomy stalls, carded daily and turned into a protected barnyard during each pleasant day. They were fed twice daily; the hay was given some time before milking in the afternoon, and the grain just before milking, while in the morning the grain was given just before and the hay just after milking. Water was supplied constantly by aid of a self-watering device.

Character and Cost of Feeds. — The hay was an admixture of timothy, red top and some clover. Unfortunately, it varied in texture, and during part of the experiment it was rather coarse, which caused the animals to leave small amounts on different days. The bran was of the spring variety. The cottonseed meal was of fair quality, containing about 39 per cent. of protein. The corn meal was local-ground and of good quality. The Molassine meal has already been described. The market price of the several feeds at the time of the experiment was as follows: —

	Per Ton.
Hay,	$23 00
Corn meal,	26 00
Cottonseed meal,	34 00
Wheat bran,	27 00
Molassine meal,	40 00

Weighing the Animals. — Each cow was weighed for three consecutive days at the beginning and end of each half of the trial, before the afternoon feeding.

Sampling Feeds and Milk. — The hay was sampled at the beginning, middle and end of each half of the trial in the usual way, as described in other experiments of this character. The grains were sampled daily, and the samples preserved in glass-stoppered bottles and brought to the laboratory at the end of each half of the trial for dry-matter determinations and complete analyses.

The milk of each cow was sampled daily for five consecutive days for each week of the trial. The usual method of sampling was followed.

TABLE III. — *Analysis of Feedstuffs.*

CHARACTER OF RATION.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Hay,	10.54	9.29	2.22	42.94	28.86	6.15
Bran,	12.13	16.36	4.80	51.46	9.19	6.06
Cottonseed meal,	7.84	39.10	8.51	27.68	10.60	6.27
Corn meal,	14.06	8.87	3.67	70.17	1.98	1.25
Molassine meal,	19.61	9.08	0.41	57.71	6.06	7.13

TABLE IV. — *Total Rations consumed by Each Cow (Pounds).*

Corn Meal Ration.

NAME.	Hay.	Bran.	Cottonseed Meal.	Corn Meal.	Molassine Meal.
Fancy II.,	314	42	21	84	–
Cecile,	328	42	21	84	–
White,	464	63	53	105	–
Amy,	369	42	21	84	–
Betty,	371	42	21	84	–
Samantha II.,	483	63	42	105	–
Totals for herd,	2,329	294	179	546	–

Molassine Meal Ration.

NAME.	Hay.	Bran.	Cottonseed Meal.	Corn Meal.	Molassine Meal.
Fancy II.,	330	42	21	–	84
Cecile,	360	42	21	20	63
White,	478	62	51	–	103
Amy,	344	42	21	–	84
Betty,	358	42	21	–	84
Samantha II.,	471	63	42	–	105
Totals for herd,	2,341	293	177	20	523

TABLE V. — *Average Daily Ration consumed per Cow (Pounds).*

CHARACTER OF RATION.	Hay.	Bran.	Cottonseed Meal.	Corn Meal.	Molassine Meal.
Corn meal,	18.5	2.3	1.4	4.3	–
Molassine meal,	18.6	2.3	1.4	–	4.3[1]

[1] Including 20 pounds of corn meal fed Cecile.

The average daily amount of rations fed was practically the same for both periods. This does not, however, take into account the actual dry matter fed. The small amount of corn meal that it was found necessary to feed Cecile in order to induce her to eat the Molassine is figured as Molassine meal.

Table VI. — *Digestible Organic Nutrients in Average Daily Rations (Pounds).*

Character of Ration.	Crude Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Total.[1]	Nutritive Ratio.
Corn meal,	1 98	3.33	8 77	.54	15.27	1:6.7
Molassine meal,[2]	1.89	3.35	7.80	.39	13.90	1:6 4

[1] Including fat x 2.2. [2] With corn meal fed Cecile figured as Molassine meal.

The total average daily nutrients were somewhat less for the Molassine ration than for the corn meal ration, due largely to the fact that the Molassine meal contained rather more water and less digestible matter than the corn meal.

Table VII. — *Herd Gain or Loss in Live Weight (Pounds).*

Character of Ration.	Gain.
Corn meal,	15
Molassine meal,	5

The gain in weight for both periods is insignificant, and simply demonstrates that the animals were receiving sufficient food to maintain body and milk requirements.

Table VIII. — *Total Yield of Milk Products (Pounds).*

Corn Meal Ration.

Cows.	Total Milk (Pounds).	Daily Milk (Average).	Total Solids (Pounds).	Total Fat (Pounds).	Butter Equivalent (Fat + ⅙).	Average Per Cent. Total Solids.	Average Per Cent. Fat.
Fancy II.,	405.4	19 3	55.42	19.42	22.66	13.67	4 79
Cecile,	384.0	18 3	53.07	18 20	21 23	14 82	4.74
White,	771.8	36 8	96.24	34.04	39 71	12 47	4 41
Amy,	456 7	21 7	62.57	21 88	25.53	13.70	4 79
Betty,	377.7	18.0	53 10	18.17	21 20	14.06	4.81
Samantha II.,	715.9	34 1	89 99	26.92	31.41	12.57	3 67
Total,	3,111.5	24 7[1]	410.39	138.63	161.74	13.19[1]	4.46[1]

[1] Average.

TABLE VIII. — *Total Yield of Milk Products (Pounds)* — Continued.

Molassine Meal Ration.

Cows.	Total Milk (Pounds).	Daily Milk (Average).	Total Solids (Pounds).	Total Fat (Pounds).	Butter Equivalent (Fat + ⅙).	Average Per Cent. Total Solids.	Average Per Cent. Fat.
Fancy II.,	370.6	17.6	49.29	16.71	19.49	13.30	4.51
Cecile,	300.7	14.3	41 26	14.04	16.38	13.72	4.67
White,	631.3	30.1	75.57	25.38	29.31	11.97	4.02
Amy,	429.1	20.4	58 31	21.15	24.68	13.59	4.93
Betty,	368.3	17.5	51 19	17.75	20.71	13.90	4.82
Samantha II.,	621.3	29.6	77 35	24.54	28.63	12.45	3.95
Total,	2,721.3	21.6[1]	352.97	119.57	139.50	12.97[1]	4.38[1]

[1] Average.

It will be seen from the foregoing table that the cows produced substantially 14 per cent. more milk and 16 per cent. more solids and fat on the corn meal ration than they did on the Molassine ration. The milk produced during the corn meal period contained a slightly higher percentage of total solids and fat than did that produced in the Molassine period. This, however, may have been within the limit of error.

TABLE IX. — *Food Cost of 1 Quart of Milk and 1 Pound of Butter for Each Ration.*

CHARACTER OF RATION.	Total Cost of Ration.	Cost of 1 Quart of Milk.	Cost of 1 Pound of Butter.
Corn meal,	$42 61	$0.031	$0 26
Molassine meal,	46 19	.038	33

Adverse Influences. — 1. The fact that the cow Cecile could not be induced to eat the Molassine, and that it was necessary to substitute 1 pound of corn meal for 1 pound of Molassine. As figured, however, this should benefit the Molassine ration.

2. The hay fed did not run as uniform in quality as could have been desired. As all the cows received the same hay each day this should not affect the results obtained.

3. The total corn meal ration contained 18 pounds more dry matter than did the Molassine ration. When this is applied to the average daily ration the difference is very slight.

General Conclusions. — 1. Molassine meal is essentially a carbohydrate feed, but differs from corn meal in containing more water, fiber and ash, and less fat and carbohydrates. While the protein content is about the same, the protein of the Molassine contains approximately 70 per cent. of amido compounds which are not as valuable as true protein.

2. Molassine meal was found to contain about 470 pounds less digestible matter to the ton than corn meal.

3. In a feeding experiment with 6 cows the Molassine meal ration produced about 14 per cent. less milk and 16 per cent. less solids and fat than did the corn meal ration.

While molasses mixed with moss or peat (of which Molassine meal is a type) renders the former easily handled, and while such a mixture may be used to advantage in some cases, it is believed that at prevailing prices it is likely to prove a decidedly expensive feedstuff, especially for dairy animals.

(4) *Molassine Meal for Horses.*

Mention has already been made of the fact that mixtures of moss or peat and molasses are in common use in Germany, France and England. There is no feedstuff the value of which has been so thoroughly discussed and disputed as has this feed mixture.

The late O. Kellner [1] considered it expensive, recognizing that its nutritive value was to be found only in the 75 per cent. of molasses which it contained. He advised the use of plain molasses, or molasses mixed with bran or other feedstuff.

Lavalard,[2] one of the French authorities on the nutrition of the horse, conducted long-continued experiments, using one-fourth *Tourbe-Melassée* and three-fourths oats, corn and beans, together with some 7 to 8 pounds daily of chopped straw. He states that this combination has given the best results, the animals completely consuming the ration, which was never the case with the ordinary ration fed. He further states that as a result of feeding this ration, large numbers of cavalry horses were well nourished and equal to the work required of them, and with a noticeable decrease in the intestinal troubles which usually occur. The introduction of molasses in the ration led him to fear the injurious effects of the potash salts. His long experience, however, enables him to say that these salts acted both as a tonic and stimulant.

The writer has fed Molassine meal to farm horses and found it to be readily eaten and in no way injurious. The horses to which it was fed were in normal condition beforehand.

In spite of its worthlessness as a food, the moss serves as a satisfactory carrier of the molasses. Emphasis has already been placed upon the high cost of the Molassine meal in proportion to its nutritive value.

(5) *General Statement concerning Molasses as a Foodstuff.*

Molasses has been in use for a considerable time both in Europe and America, either fed by itself or as a component of mixed feeds for all kinds of live stock.

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[1] Die Ernährung d. Landw. Nützthiere, Sechste Auflage, p. 378.

[2] L'alimentation du Cheval, p. 62.

As a result of numerous experiments it has been shown to have substantially three-fourths the nutritive value of corn meal. Contrary to popular opinion, molasses does not improve the digestibility of other foods with which it is fed; it decreases or depresses their digestibility.[1] As a result of his reading and own experiments, the writer desires to repeat previous statements concerning the use of molasses: —

1. *For Dairy Stock.* — No advantage is to be gained by northern farmers from the use of molasses as a food in place of corn meal and similar carbohydrates. As an appetizer for cows out of condition, and for facilitating the disposal of unpalatable and inferior roughage, 2 to 3 pounds of molasses daily undoubtedly would prove helpful and economical.

2. *For fattening Beef Cattle.* — Some 3 pounds daily may be fed advantageously, especially during the finishing process, when the appetite is likely to prove fickle. The object at such times is to make the food especially palatable, and thus induce a maximum consumption, and also to secure a bright, sleek appearance.

3. *For Horses.* — In spite of the many favorable reports relative to the use of molasses, the writer is not inclined to recommend to northern feeders its indiscriminate use in the place of the cereals and their by-products. As an appetizer and tonic for horses out of condition, and for hard-worked horses, as a valuable colic preventive, and for improving the palatability of rations, 2 to 3 pounds daily of molasses undoubtedly would prove productive of satisfactory results. Frequently, however, horses that have become accustomed to molasses as a component of the ration refuse to eat freely should the molasses be removed.

(6) *How to feed Plain Molasses.*

When molasses is fed in its natural state it should be warmed if necessary, diluted somewhat with warm water, and mixed with the bulk of the grain ration or with finely cut hay or straw. Molasses may also be placed in a sack suspended in a barrel of water over night and the resulting liquid given as a drink.

2. COTTONSEED MEAL AND COTTONSEED HULLS.[2]

Cottonseed meal is the ground cake resulting from the extraction of cottonseed oil from the cottonseed kernel. Cottonseed meal containing not more than 8 per cent. fiber nor less than 40 per cent. protein is to be preferred to that containing more fiber and less protein. Our compilations of analyses of cottonseed meal made since the adoption of the feedstuff law show the following average protein, fat and fiber content for the various years: —

[1] Mass. Expt. Sta., 22d report, pp. 82–131.

[2] Prepared entirely by Mr. Smith.

Year.	Number of Samples.	Protein (Per Cent.).	Fat (Per Cent.).	Fiber (Per Cent.).
1897–1902,	93	46.2	11.2	5.8
1902–1906,	190	45.4	9.6	6.4
1906–1911,	85	42.0	9.2	7.3
1911,	30	41.0	8.2	7.7
1912,	64	41.0	7.7	8.4
1913,	87	40.2	7.7	9.2
1914,	50	40.2	7.6	9.4

There is a growing tendency to incorporate more hulls in cottonseed meal, as is clearly demonstrated in the gradual and consistent increase in the fiber content of the meals collected during the last seventeen years. The preceding average does not show the worst samples, as a number of those collected during 1914 contained as high as 12 per cent. of fiber.

Cottonseed meal has long been considered the most economical and satisfactory protein concentrate that the New England dairy farmer could buy, and its value has been set forth by experiment station officials and practical feeders. If it is to continue to hold its high place this gradual decrease in its quality must stop.

Bartlett has demonstrated in a very striking manner the wide difference in the feeding value of cottonseed meal containing different proportions of fiber or hulls by actual digestion tests with sheep, as follows:[1] —

(1) *Composition of Four Grades of Cottonseed Meal used in Digestion Experiments.*

Grade.	Water (Per Cent.).	Ash (Per Cent.).	Protein (Per Cent.).	Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Fat (Per Cent.).
Very high,	8.01	7.59	46.75	6.23	21.64	9.78
Dark colored,[2]	12.72	7.05	42.50	7.67	14.64	8.62
Medium,	11.60	6.50	34.13	13.58	19.83	8.90
Low,	9.52	4.70	23.81	21.43	30.53	6.20

[1] Bul. No. 115, Maine Experiment Station.

[2] Due to fermentation.

(2) *Digestion Coefficients with Sheep.*

Grade.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Protein (Per Cent.).	Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Fat (Per Cent.).
Very high,	90 0	95.3	83.3	–	95 9	100 0
Dark colored,[1]	85.8	89.9	82.2	–	94.7	97.2
Medium,	73.0	78.0	83 6	43.5	82.1	94.6
Low,	61.4	64 1	72.6	37.8	67.8	90 1

[1] Due to fermentation.

Pounds of Digestible Nutrients in 100 Pounds of the Different Grades of Cottonseed Meal.

Grade.	Organic Matter (Pounds).	Protein (Pounds).	Nitrogen-free Extract (Pounds).	Fat (Pounds).
Very high,	80 4	39.0	20.8	9 8
Dark colored,[1]	72 2	35.0	13.9	8.4
Medium,	63.9	28.5	16.3	7.3
Low,	55.0	17.3	16.5	5.6

[1] Due to fermentation.

It will be seen that 100 pounds of low-grade cottonseed meal contained about 30 per cent. less digestible organic matter than the high-grade material. The addition of hulls to cottonseed meal, even in small amounts, lessens its feeding value in two ways: first, it decreases its protein content; second, it impairs its digestibility. Since the quality of the meal sold in Massachusetts is gradually growing poorer, consumers have a right to know just where this decreasing feeding value is going to stop. Manufacturers claim that it is due largely to improved processes in the extraction of the cottonseed oil.

(3) *Cottonseed Feed Meal.*

Cottonseed feed meal is either a mixture of cottonseed meal and crude hulls or of cottonseed meal and cottonseed hull bran. When the mixture consists of cottonseed meal and hulls it is usually derived from the Sea Island cottonseed, to which no lint adheres, and is theoretically the entire seed (both kernel and hulls) ground together after the extraction of the oil.

Cottonseed hull bran is the cotton hull from which the lint has been removed by a special process. In the preparation of cottonseed for the manufacture of oil the lint is not entirely removed. A number of mills have been established that take the hulls from the cottonseed crushers and remove the last trace of lint. Only a small proportion of the hulls produced, however, are entirely delinted.

Here follow the analyses of cottonseed hulls, cottonseed hull bran, and cottonseed feed meal made at the experiment station: —

Material.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Cottonseed hulls,[1]	11.0	5.3	2.4	39.0	39.7	2.6
Cottonseed hull bran,	11.0	2.3	1.1	48.7	35.0	1.9
Cottonseed feed meal,[2]	10.3	21.3	4.9	39.8	19.0	4.7

[1] This analysis was made in connection with some experimental work at the experiment station prior to 1900. Owing to improved processes in the separation of meats and hulls, cottonseed hulls now contain less protein and fat than formerly.

[2] Analysis of sample used in digestion experiment.

Experiments have shown about 41 per cent. of the cottonseed hulls to be digested and utilized by ruminants, as compared with 55 per cent. in case of timothy hay. In other words, in 1 ton of material there would be 820 pounds of cottonseed hulls digested as compared with 1,100 pounds of timothy hay. Data are not available for the cottonseed hull bran, but it is not believed its digestibility is much greater. The results of a digestion trial with cottonseed feed meal made at this station follow: —

Digestion Coefficients for Cottonseed Feed Meal.

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V.,	59.30	47.20	73.57	32.31	61.35	102.97[1]
VI.,	57.15	51.53	76.34	19.88	61.04	98.25
Average,	58.23	49.37	74.96	26.10	61.20	100.66
High-grade cottonseed meal for comparison.	79.00	84.00	84.00	35.00	78.00	94.00

[1] This figure simply shows that all of the fat was digested, together with 2 per cent. more of the fat in the hay fed than was digested when the hay was fed alone.

The low fiber digestibility is due to the tough, woody character of the hull. This material contains only about three-fourths of the total digestible dry matter of cottonseed meal of good quality. Furthermore, since it contains much less digestible protein and two and one-half times as much total fiber as genuine cottonseed meal, it is not worth more than one-half as much for animal feeding. At the present time (October, 1914) it is being offered at a price about three-fourths that of choice cottonseed meal. Judging from its analysis it probably contains 1,000 pounds of choice cottonseed meal and 1,000 pounds of cottonseed hull bran to the ton.

(4) *Conclusions.*

I. On the basis of analyses made during the last seventeen years, it is evident that the quality of cottonseed meal sold in Massachusetts is gradually growing poorer.

II. The addition of cottonseed hulls or cottonseed hull bran to choice cottonseed meal noticeably decreases its digestibility.

III. Cottonseed feed meal, being a mixture of approximately 1,000 pounds of choice cottonseed meal and 1,000 pounds of cottonseed hull bran, does not have much over one-half the feeding value of choice cottonseed meal, while it sells for three-fourths as much.

IV. While cottonseed hulls and cottonseed hull bran can probably be used to advantage in the south, they are not worth the consideration of the northern feeder, either as a product by themselves or as an admixture in good cottonseed meal.

3. COCOA SHELLS.

Cocoa shells are the hard, outside coating or bran of the cocoa bean. They are dark brown in appearance and brittle in texture. They comprise from 10 to 16 per cent. of the bean. The entire residue, however, removed from the bean and included as cocoa shells amounts to from 16 to 25 per cent. The output for the United States has been estimated at 6,700 tons. Up to the present time their use in this country as a feeding stuff has been quite limited, although they are now known to be used in several poultry mashes and in one brand of calf meal. In Europe they are used as a partial food for horses and cattle and as an adulterant for oil cakes. Large quantities are also used by the Swiss as a feed for draft oxen, thus utilizing the residue from their chocolate factories. It is held that they act as a stimulant to the nerves and muscles and enable the animals to do a greater amount of work. [1]

(1) *Chemical Composition.*

Number.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
A,[2]	4.50	8.43	13.90	12.65	55.61	4.91
B,[3]	10.00	7.40	14 30	15.80	46.30	6.20

[1] Pott, Handbuch d. thierschen Ernährung, etc., 3rd Bande pp. 136–141.

[2] As used in digestion trial.

[3] Kellner's tabulation.

The difference between the American and German figures is within the limits of variations in different samples.[1]

(2) *Digestion Coefficients with Sheep.*

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
I.,	56.55	13.04	4.41	41.41	75.75	100.41
II.,	58.59	14 32	18.52	59 91	71.16	100.54
Average,	57.52	13.64	11.47	50.66	73 46	100.48
German coefficients,[2]	36.00	–	5.00	21.00	48.00	84 00

It will be seen that the product used by Kellner for some reason was much less digestible than that used by ourselves.

Pounds Digestible in 100 Pounds of Shells.

	Massachusetts.	Kellner.
Protein,	1.53	.71
Fiber,	6.45	3.31
Nitrogen-free extract,	40.60	22.22
Fat,	4.91	5.21
Total,	53 49	31 45

It is quite evident that the proteid matter is only slightly digestible and may be considered a negligible quantity; hence the value of the product consists of the digestible fiber, fat and extract matter. On the basis of his results, Kellner remarks that the cocoa shells have no more feeding value than straw.

The net available energy on the basis of our own digestion trials is 63 as compared with corn meal equal to 100. When, however, one considers their non-palatability and their rather objectionable appearance, together with the results of other investigations, it does not seem advisable to rate them as having more than one-half the feeding value of corn meal.

(3) *Feeding Trials.*

A number of milch cows were fed from 2 to 3 pounds, daily, of the cocoa shells, both ground and unground, mixed with other grains. One cow was induced to eat as high as 5 pounds when mixed with malt sprouts and

[1] Foreign workers have shown the presence of the alkaloids caffein and theobromine, also a considerable percentage of pentosans. Fowler, in the laboratory of the Massachusetts Agricultural College, has determined the percentages of the alkaloids, and has found also 8.3 per cent. of pentosans, 7.3 per cent. of galactans, a little over 1 per cent. of starch and traces of sugar.

[2] Obtained by Kellner.

corn meal. It was difficult to induce the animals to eat the shells unground. It was not possible to make any comparative tests of the effect of a definite amount of ground shells upon milk production, as compared with some other grain, for the reason that a sufficient number of animals was not available at the time. The observation simply indicated that the animals would eat the ground shells when mixed with other grain.

(4) *Manurial Value.*

The average of two analyses of cocoa shells showed them to contain: —

	Per Cent.
Nitrogen,	2.45
Potash,	2.92
Phosphoric acid,	.69

The nitrogen was found to be about one-third available. The balance would, of course, be of use to plants from year to year. Based on the above analyses the shells have a commercial value of about $6 a ton as a fertilizer.

(5) *Conclusions.*

The results of our study of cocoa shells show them to have a feeding value about one-half as high as corn meal. They are best suited for dairy animals, while in foreign countries they are used also as a partial food for horses. Dairy animals will, as a rule, not eat them unground. If they can be had at a sufficiently low price the ground shells can be used in amounts of from 1 to 3 pounds daily mixed with the grain ration. Because of their low digestibility it is doubtful if they can be purchased to advantage as a food for horses. As a source of fertility they are evidently not worth much more than the cost of cartage and spreading. They may also be used for bedding purposes.

4. WHEAT OR GRAIN SCREENINGS.

Grain screenings consist of the light seed, weed seeds, chaff and dirt separated from grain in the process of winnowing. The composition of grain screenings depends upon the kind of seed from which they are separated and upon their freedom from dirt and chaff. They necessarily vary so much in composition that no general statement as to their value can be made. Where screenings contain a large amount of straw and chaff they cannot be considered much superior to straw; on the other hand, screenings free from chaff and dirt, and containing nothing but light grain and weed seed, possess considerable feeding value.

Grain screenings are but little used by themselves as a feeding stuff in Massachusetts, but are found on the market as a component of molasses feeds, of wheat by-products, and occasionally of the so-called stock feeds. In the west screenings have been used for fattening sheep. Formerly one objection to the use of screenings in proprietary stock feeds was due to the fact that they contained many whole weed seeds which passed through the animal undigested and found their way on to the land ready to grow, and thus added to the labor of keeping cultivated land free from weeds. With improved processes of manufacture the screenings are now mostly finely ground and their germinating property destroyed.

(1) *Physical Appearance.*

Two lots of screenings were obtained from a commission merchant in Milwaukee. They were quite similar in physical appearance. The following materials were identified in sample No. 1; light oats, oat hulls, wheat, wheat refuse, smutted grain, yellow foxtail, green foxtail, corn cockle, bindweed, flax, lady's thumb, charlock, wild mustard, rape, lamb's-quarters, large smartweed, chaff of various sorts, wild sunflower, pigweed, timothy, shepherd's-purse, chess, oat grass, wild oats, rye and corn, together with a few unidentified seeds. Both lots used must be considered as of good quality for screenings, as they did not contain excessive amounts of broken straw, chaff or dirt.

(2) *Chemical Composition.*

Sample.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
No. 1, ...	8.0	4.9	15.6	9.1	54.7	7.7
No. 2, ...	11.5	3.8	15.5	7.3	57.2	4.7
Wheat bran for comparison, .	10.0	6.2	16.1	10.0	53.3	4.4

(3) *Digestion Coefficients obtained with Sheep.*

Lot I.

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V., ...	57.57	27.36	78.88	-	63.76	86.18
VI., ...	60.65	26.10	82.97	-	65.33	87.41
Average, ...	59.11	26.73	80.93	-	64.55	86.80

Lot II.

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V., ...	64.93	-	62.26	-	79.54	87.67
VI., ...	68.58	-	63.01	-	84.12	92.50
Average, ...	66.76	-	62.64	-	81.83	90.09
Average for both lots, . .	62.94	-	71.79	-	73.19	88.45
Wheat bran for comparison,	66.00	-	77.00	39.00	71.00	63.00

The difference shown in the digestibility of the two lots can probably be accounted for by the fact that the first lot contained more fiber and less nitrogen-free extract than did the second. The fiber contained in both lots did not appear to be at all digestible, indicating somewhat of a depressing effect of the wheat screenings upon the fiber digestibility of the hay, and also that the fiber contained in the weed seeds of the screenings was of decidedly inferior character. In chemical composition and digestibility the screenings did not appear to vary greatly from wheat bran.

(4) *Conclusions.*

The chemical composition and the results of the digestion trials indicate that these particular screenings possessed a considerable nutritive value. Owing to the wide difference in the character of screenings the results obtained should not be considered as representative for all classes of screenings, but only for those reasonably free from dirt, chaff, straw and an excess of noxious seeds. When used either by themselves, or as a component of molasses, wheat or stock feeds, they should be finely ground, and would then approximate wheat bran in the amount of nutritive material they contain.

5. FLAX SHIVES.

Flax shives, sometimes incorrectly called flax bran, consist of the ground refuse stalks and pods of the flax plant. They are sometimes used as a component of stock and molasses feed, and have been found on sale in Massachusetts as a substitute for wheat bran. They have the appearance of finely ground hay. The analysis of two samples at the experiment station showed that this material may vary widely in chemical composition.

(1) *Chemical Composition.*

Sample.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
No. 1, ...	6.8	12.1	6.1	45.2	27.7	2 1
No. 2,[1]	10.0	5 0	14.9	32.3	34.9	2.9
Average, ...	8.4	8.6	10.5	38.8	31.3	2.5

[1] Used in digestion trials.

(2) *Digestion Coefficients obtained with Sheep.*

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V., ...	42.94	21.86	79.98	22.00	41.27	92.26
VI., ...	47.82	23.69	82.08	29.58	45.63	93.09
Average, ...	45.38	22.78	81.03	25.79	43.45	92.68

This experiment showed flax shives to have a digestibility of about 45 per cent. as compared with 66 per cent. for wheat bran; in other words, 1 ton of flax shives would contain only 900 pounds of digestible matter, while wheat bran contains about 1,140 pounds. Their high fiber content requires considerable extra energy for their digestion. This fact, coupled with their small amount of protein and their low total digestibility, renders them in no way economical for eastern feeders. As a component of mixed feed they must be considered as a filler or adulterant. They may serve, where they are produced, as a partial feed for sheep or steers.

6. MELLEN'S FOOD REFUSE.

This material is sold to a limited extent in eastern Massachusetts and consists of the residue resulting from the manufacture of an infant food. The original ingredients used in this food are malt, flour and bran, the soluble and more digestible parts of these materials going into the infant food.

(1) *Chemical Composition.*

	Per Cent.
Water,	6.98
Ash,	4.07
Protein,	12.57
Fiber,	16.97
Nitrogen-free extract,	55.48
Fat,	3.93

(2) *Digestion Coefficients with Sheep.*

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
V.,	54.13	–	50.64	42.83	61.85	83.33
VI.,	48.17	–	39.24	46.23	54.87	83.43
Average,	51.15	–	44.94	44.53	58.36	83.38

Pounds Digestible Organic Matter in 100.

Protein,	5.66
Fiber,	7.64
Nitrogen-free extract,	32.18
Fat,	3.26
Total,	48.74

Mellen's Food refuse was found to contain 975 pounds of digestible organic nutrients as compared with 1,140 pounds for wheat bran. Its low digestibility is due, no doubt, to the fact that the more digestible parts of the ingredients used are to be found in the prepared food itself. It has a net energy value of 44.58 therms as compared with 49 therms for wheat bran, or as 90 is to 100. It could be used as a component of the grain ration for either cattle or horses, providing it could be purchased for substantially three-fourths of the cost of wheat bran. Two to three pounds daily would be considered a normal amount mixed with other higher grade concentrates.

7. CXX FEED.

A by-product known as CXX Feed has been found to some extent on the Massachusetts market. This material bears the name of the Postum Cereal Company, and is supposedly the insoluble residue of Instant Postum, prepared by roasting a mixture of wheat, wheat bran and molasses.

(1) *Chemical Composition.*

	Per Cent.
Water,	9.18
Ash,	2.49
Protein,	17.77
Fiber,	16.45
Nitrogen-free extract,	51.28
Fat,	2.83

(2) *Digestion Coefficients with Sheep.*

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract	Fat.
V.,	45 73	–	19.85	20.00	64.97	77 26
VI.,	40.08	–	19.76	6 76	59.98	78 53
Average,	42 91	–	19.81	13 39	62 48	77.90

Pounds Digestible Organic Matter in 100.

Protein,	3.52
Fiber,	2.21
Nitrogen-free extract,	32.04
Fat,	2.20
Total,	39.97

The results of the experiment show the CXX Feed to have a very low digestibility, probably due to the roasting that the product undergoes, and to the fact that much of the very digestible soluble carbohydrates has been removed. The protein and fiber appear to be of little nutritive value, and the material as a whole must be pronounced quite inferior for feeding purposes.

THE TECHNICAL DESCRIPTION OF APPLES.

BY J. K. SHAW.

Introduction.

This paper aims to set forth certain methods and terms which the writer has found useful in the description of apple trees and fruits. It contains little that is new to the pomological world, but is, rather, a compilation of methods and terms of description gathered from many pomologists of our own and former times. This matter has been brought together and arranged in a definite and systematic manner. It is not intended to be complete in itself, but should be used in connection with a good textbook or reference work on systematic pomology.

The best presentation of tree description may be found in Thomas' "American Fruit Culturist." For description of the fruit, Beach's "Apples of New York" and Hansen, in the "American Horticultural Manual" Vol. II., are the most complete and satisfactory. Other books giving helpful discussions, especially of fruit characters, are Waugh's "Systematic Pomology," Warder's "American Pomology" and Robert Hogg's "British Pomology." Among the German works, Lucas' "Einleitung in das Studium der Pomologie" is most complete and useful.

A written description of a variety of apples may be made from one or more typical specimens before the writer, or it may be written from memory or compiled from notes after one has become familiar with the variety. Two kinds of variety description ought to be recognized, — first, a systematic description which takes account of all characters of the tree and fruit which can have taxonomic value, and second, the commercial description, which is a presentation of all the characters and qualities of a variety that are of interest and value to the man interested in the practice of fruit growing. Most variety descriptions belong to the former class, though some give considerable attention to the commercial phase. Commercial descriptions are of much the greater interest and value to the practical orchardist, and they ought to be more clearly recognized and we ought to have more of them. The distinction between the two is an arbitrary one, and is made for convenience and for the sake of emphasizing those qualities that are of paramount interest to the commercial fruit grower.

The Systematic Description.

The systematic description involves all the characters of the tree and fruit having taxonomic value. In the description blank suggested here an effort has been made to classify these characters, and as far as possible to reduce each to a single unit. Under each heading a single character is to be considered and described, usually with one appropriate word. Rarely will several words be required. In the text and in Fig. 1 descriptive words are suggested. While these are not all that may be required, we believe that additional ones will not often be needed, with the exception of qualifying adverbs. Words such as *very, slightly, much, rarely* and many others will be called into use freely, but it is felt that it is unnecessary to suggest them all through the discussion of the description blank. Where additional terms are used one should be careful that he understands the relation of the new term to those given, and if necessary he should somewhere explain its meaning and relationship. One of the confusing things in fruit descriptions is the use in individual descriptions of different terms with nearly or quite the same meaning, or of a single term with slightly different meanings. Of course, it is impossible to altogether avoid such confusion because apples vary so greatly, but every effort should be made to make things as definite and exact as possible.

In making a systematic description one should state, either directly or by implication, the scope of his description,— whether it is of a single apple, a plate of five specimens, or the variety as it grows over a certain section of the country, as Massachusetts, New England, the Central Mississippi valley or North America. The description of a few specimens is a comparatively simple matter, and may be made in a few minutes by the trained pomologist with the specimens before him. The description of a variety as it grows over a considerable area is more complicated, and can be made only after a thorough study of the behavior all over the district comprehended in the description. In such descriptions we should strive to describe the type of the variety, but as a variety may vary greatly if a district of any size is considered, it becomes very desirable to delimit as well as we can the range of variation. Perhaps the best method to pursue is to give the type and follow it immediately by a statement of the variation. Thus we may describe the form of the Ben Davis for North America as "*roundish-conic,* varying from *oblate-conic* to *oblong-conic,*" and other characters in a similar fashion.

Of course such a description will be cumbersome, and for many purposes an abridged form may be found sufficiently complete and more acceptable. Nevertheless, for a thorough college course in systematic pomology, or for exact descriptive work in experimentation, this type of description ought to have a place.

In the description of the individual tree or fruit the location or source should always be given, and if possible the soil and cultural conditions under which it was grown. It is well to give the date on which the description was made, and of course the name of the person responsible for the work.

Tree Description.

Tree. — In the systematic description of the tree the first thing stated is its age. If not definitely known it should be estimated. The next point is the size which may be *small, medium* or *large.* This should of course be

Variety From Soil

TREE, age size *small, medium, large* vigor *weak, strong, moderate, very strong*

form *flat, round, oval, upright, spreading, drooping* density *dense, medium, open*

SHOOTS, length *short, long, medium* size *stout, medium, slender* direction *upright, drooping, diverging, ascending, spreading, regular*

straightness *straight, zigzag* curvature *curved, not curved* internodes *short, medium, long*

BARK, color *green, yellow, orange, red* scarf-skin

surface *shining, medium, dull* thickness *thick, medium, thin* pubescence *much, medium, thin, fine, coarse*

Lenticels, number *few, medium, many* size *small, medium, large*

form *oval, roundish, flattened* color *white, gray, brown* position *even, raised*

WOOD, color *green, yellow* hardness *hard, medium, soft*

flexibility *stiff, medium, flexible* pith *narrow, medium, wide*

BUDS, size *small, medium, large* form *roundish, ovate, oval, slender* color *brown, red*

position *free, appressed* surface *pubescent, smooth*

LEAVES, Petiole, length *long, medium, short* size *slender, medium, stout*

color *green, red* surface *smooth, pubescent*

Stipules, size *small, medium, large* form *wide, medium, narrow*

Blade, size *very small, medium, small, above medium, below medium, large, very large* form *flat, folded* mid-rib *straight, reflexed*

sides *even, waved, wrinkled, crumpled* outline *oval, ovate, oblong*

base *broad, rounded, narrow* apex *broad, medium, narrow* point *small, medium, large, blunt, acute, acuminate*

general color *light green, dark green* vein color *green, red*

position *erect, spreading, drooping* thickness *thick, medium, thin*

serratures, nature *sharply serrate, serrate, dentate, crenate* direction *strongly forward, forward, outward*

size *small, medium, large* regularity *regular, irregular, double*

curvature *curved, straight* depth *deep, medium, shallow* space *distinct, indistinct.*

surface *dull, shining* texture *coarse, fine* pubescence *short, long, fine, coarse, woolly*

FLOWER

CHARACTERISTICS

Described by Date

Massachusetts Experiment Station Department of Pomology

FIG. 1. — Description blank, for the tree, with terms used.

stated in relation to the age of the tree. The size of the tree is determined by the rate of growth in the past, while the vigor measures its current rate of growth as indicated by the length and size of the shoots and the color, size and abundance of the foliage. In vigor the tree may be *weak, moderate, strong* or *very strong.* Next comes the form of the tree which is often characteristic and important in trees that are approaching or have reached maturity. Most varieties begin to take on their characteristic form by the time they are four to six years old. The form of the head may be *flat, round, oval, upright, spreading* or *drooping.* The density of the head is determined by the thickness of its branches and by the abundance of their foliage. It may be *dense, medium* or *open.*

Shoots. — The shoots comprise the last or current season's growth of the more vigorous branches. In very young trees they indicate in some measure the adult form of the tree. Their length should be estimated on the basis of a full season's growth. They may be *short, medium* or *long,* and if the average length in centimeters or inches can be given, so much the better. In size they may be *stout, medium* or *slender,* and if the diameter preferably in millimeters, 2 inches or less above the last annual ring, is given, it adds to definiteness. The direction of the shoots is of special significance in very young trees. They may be *upright, diverging, spreading, drooping, ascending* or *irregular.* The direction may be quite satisfactorily determined by means of a simple protractor. It should be taken on a main branch that is perpendicular. Shoots that are diverging form an angle of about 45°, while ascending shoots are like upright ones, except that they are more distinctly curved near the base. Under straightness we record whether the shoots are *straight* or *zigzag.* In the latter case the successive internodes do not lie in the same direction, but alternate back and forth. Under curvature the shoots may be more or less *curved* or *not curved.* The length of the internodes varies somewhat in different varieties, and they may be *short, medium* or *long.*

Bark. — The color of the bark varies with the season. In the summer it is some shade of *greenish olive* or *yellowish olive,* and the color darkens with the falling of the leaves to a *greenish, yellowish* or *reddish brown.* The full description of a variety ought to include both the summer color and the winter color. The summer color should be taken on wood of the previous season's growth, as that of the current season's growth is apt to be variable. The surface may be *shining* or *dull,* and in thickness the bark may be *thick, medium* or *thin.* The amount of pubescence on the young shoots — *much, medium* or *little* — should be mentioned, and whether it is *fine* or *coarse.*

The lenticels are often characteristic of the variety, and they seem to be quite dependable in identification. The number — *few, medium* or *many* — is most valuable, and should be carefully noted. Their size — *small, medium* or *large* — should find mention, also their form, which is commonly *roundish* but may be *oval* or *flattened.* Their color is commonly *whitish, gray* or *brown.* The position of the lenticels is of especial importance, and refers to whether they are *raised* above the surface or *even* with it. This is best determined by rubbing gently the surface of the two-year-old wood, or well-matured wood of the current season's growth, with the finger or thumb.

Wood. — The color of the fresh-cut wood will generally be *greenish* or *yellowish.* Experience in pruning or whip grafting will soon demonstrate that varieties vary much in the hardness of their wood. It may be determined — as *hard, medium* or *soft* — by cutting a branch about one-half inch in diameter. The flexibility is judged by bending a small branch thus showing whether it is *stiff, medium* or *flexible.* This character is of practical importance as indicating the danger of the tree breaking under a load of fruit. The diameter of the pith may vary somewhat, and may be said to be *narrow, medium* or *wide.*

Buds. — The buds are best described from near the middle of the current season's growth and during the dormant season of the trees. We note the size, whether *small, medium* or *large;* their form, whether *roundish, oval, ovate* or *slender;* and their color, usually some shade of *brown* or *red.* Their position with respect to the shoot may vary, so that the buds are *appressed* or clinging closely to the shoot, or they may be *free.* The surface may be *pubescent* or *smooth.*

Leaves. — The leaves of different varieties of apples are very characteristic, and offer opportunities for identification almost equal to the fruit, especially if observations can be made during the middle or the latter part of the summer, after the leaves have assumed their characteristic forms. It is necessary to use great care in the choice of specimens for description. Those near or just below the middle of the current season's growth should be chosen. Leaves growing on spurs from older wood should be ignored, as they are apt to be variable and quite unlike those on the free-growing shoots. Upright shoots well exposed to light and air, such as those in the topmost part of the tree, are to be preferred. The leaf is divided into stipules, petiole and blade. The petiole may be *long, medium* or *short,* and in size it may be *slender, medium* or *stout.* The color may be *green,* but usually it is more or less tinged with some shade of *red.* In colored petioles the amount and intensity of coloration increases with the maturity of the leaf. The surface of the petiole may be *smooth* or more or less *pubescent.*

The stipules may be *small, medium* or *large* or especially late in the season there may be *none;* in form they may be *wide, medium* or *narrow.*

In the description of the blade we consider first the size, which may be *small, below medium, medium, above medium* or *large.* In order to establish a standard of judgment of the size of leaves the following measurements of the combined length and breadth are suggested. In taking measurements the leaf should be spread out flat, and the point as defined on page 78 should be ignored.

Combined Length and Breadth.

	Inches.	Millimeters.
Very small,	Up to 4	Below 100
Small,	4–4½	100–115
Below medium,	4½–5⅛	115–130
Medium,	5⅛–6	130–150
Above medium,	6–7	150–175
Large,	7–8¼	175–205
Very large,	Over 8¼	Over 205

Form refers to the relation of the right and left sides of the leaf. If they lie in approximately the same plane the leaf is said to be *flat;* if they bend upward the leaf is more or less *folded.* The midrib may be *straight*, or if curved backward or downward it is said to be *reflexed.* The sides of the leaves may be *even*, or they may be more or less *waved* when there are not over three "waves," and *wrinkled* when there are a greater number. When the surface of the blade is more or less irregular it is said to be *crumpled.* A leaf may present various combinations of these characters. It may be *folded, reflexed* and *even; flat, straight* and *waved;* or it may present other combinations of these characters. Qualifying adverbs indicating the degree to which the leaf is folded, waved or reflexed may be freely introduced. The accompanying plates show characteristic leaves from a number of common varieties. These leaf characters have not been widely recognized, but the writer has found them peculiar to the several varieties and extremely useful in identification; in fact, one may recognize many varieties quite positively by them alone. They are most striking from midsummer until near the time of leaf fall.

The outline of the leaf is usually nearly *oval;* it may be *broad oval* or *narrow oval.* Sometimes it approaches *ovate, oblong* or *roundish.* The base includes the proximal one-third of the leaf, and it may be *broad, rounded* or *narrow*, while the apex includes the distal one-third excluding the point, and may be *broad, medium* or *narrow.*

There is usually a more or less distinct point which may be *small, medium* or *large*, also *blunt, acute* or *acuminate.*

The general color of the normal leaf is always some shade of *green*, usually *light* or *dark;* but may be *grayish, bluish* or *yellowish green.* The vein color is frequently tinged with *reddish* or *pinkish red.* The position of the leaf is its relation to the shoot on which it is borne, and it may be *erect, spreading* or *drooping*, the spreading leaf forming an angle of from 45° to 90° with the branch. Next comes thickness, and the leaf blade may be *thick, medium* or *thin.* The term "serratures" includes all forms of indentation of the margin of the leaf, and their nature may be *sharply serrate,*

serrate or *crenate*, rarely approaching *dentate*. The direction of the serratures is largely indicated by their nature, but it may be useful to make a closer specification on this point, as this is an important one in description. Their direction may be more or less *forward* or, rarely, almost *outward*. The size of the serratures is important, and should be taken strictly in proportion to the size of the leaf and not as to their absolute size. They may be *small*, *medium* or *large*. Their regularity is an important point, and they may be *regular*, *irregular* or *double*.

Sometimes the serratures are distinctly *curved*, in other cases they are *straight*, their depth is closely correlated with size, but it may add to definiteness to specify that they are *deep*, *medium* or *shallow*. Space refers to the amount of separation of the individual serratures; if widely separated they are *distinct*, if set closely they are *indistinct*. In describing the surface and texture of the blade we refer to the upper surface, while the pubescence is found on the lower surface only. The surface may be *dull* or *shining*, the texture *coarse* or *fine*, and the pubescence *short* or *long*, *fine*, *coarse* or *woolly*.

Flower. — The flower presents characters of value in systematic description, but it is available only for a brief period. Apple flowers vary in size and color, in the form of their parts, and probably in other characters. The writer has had so little opportunity to study apple flowers that he hardly feels like attempting any discussion of their exact description. Space is provided in the blank suggested for mention of such points as seem worthy of specific description.

Finally, under the heading "characteristics" we may sum up in a few words the specific characters that serve to distinguish the variety described. Careful study of any variety will usually reveal certain things about the leaves, twigs or general form of the tree that serve to identify it, and a terse recapitulation of these will be found very useful.

Fruit Description.

Size. — In the description of the fruit the first point that we consider is size. This may vary from *very small* to *very large*, or even to *extremely large*. The importance of stating the size in definite units, as inches or millimeters, as discussed on page 87, cannot be too strongly emphasized if exact work is desired. In the opinion of the writer the relation between the descriptive terms suggested and actual measurements of the cross diameter ought to be about as follows: —

APPLE, name

Size { *very small, small* } *below medium, medium* *above medium, large* *very large, extremely large* uniformity { *uniform, not uniform* }

Form { *oblate, globose* } *ovate, conic* *oblong, truncate* base { *narrow, rounded* } *broad, flattened* apex { *conic, narrow, rounded* } *broad, flattened*

cross-section { *round, oval, pentagonal* } *regular, irregular* sides { *equal, unequal* } uniformity { *uniform, not uniform* }

Color { *greenish, yellowish* } over-color { *red, crimson, scarlet, pink* } amount, %

disposition { *blushed, streaked, mottled, striped, splashed* } russet { *dense, irregular, thin, scattered* }

Bloom, amount { *much, medium, little* } kind { *waxy, greasy* }

Skin, thickness { *thick, medium, thin* } texture { *tough, medium, tender* } surface { *smooth, rough, lumpy* } *shining, dull*

Dots { *conspicuous, obscure, inconspicuous* } number { *many, medium, few* } size { *minute, small, medium, large* } form { *round, stellate, angular, areolar* }

color *white, gray, brown* distribution { *uniform, not uniform* } prominence { *sunken, even, raised, submerged* }

Cavity, depth { *deep, medium, shallow* } breadth { *wide, medium, narrow* } sides { *abrupt, steep, flaring* }

vertical outline { *acuminate, acute, obtuse* } cross-section { *round, oval, triangular, pentagonal* } markings { *russet, none* }

Stem, length { *long, medium, short* } size { *stout, clubbed, medium, slender* } direction { *straight, inclined, curved* } color { *brown, green* } surface { *smooth, pubescent* }

Basin, depth *as with cavity* breadth sides

vertical outline *as with cavity* cross-section { *wavy, ribbed, folded* } markings { *leather, cracked* }

Calyx, *open, closed* size *small, medium, large* surface *smooth, pubescent*

Calyx segments, size { *small, medium, large* } form { *obtuse, acute, acuminate* } position { *connivent, convergent, reflexed* }

Tube, length { *short, medium, long* } breadth { *wide, medium, narrow* } form { *funnel-form, conic* } stamens { *basal, median, marginal* } pistil point { *present, absent* }

ore { *axile, abaxile* } size { *small, medium, large* } position { *sessile, median, distant* } form { *oblate, oval, roundish, oblong, ovate* } core-lines { *distant, meeting, clasping* }

Cells *open, closed* size *small, medium, large* symmetry *symmetrical, unsymmetrical*

Carpels, form { *elliptical, oblong, ovate, oval, roundish, obovate* } apex { *acute, obtuse, mucronate, emarginate* } surface { *entire, slit, tufted* } concavity { *little, medium, great* }

Seeds, number *few, many* condition { *plump, medium, shriveled* } size { *small, medium, large* } color { *brown, olive, gray* }

cross-section { *roundish, oval, flattened* } longitudinal section { *long, obtuse, acute, short, acuminate* }

Axis, length *long, medium, short* direction *straight, inclined*

Flesh, color *white, yellow, green* texture { *fine, medium, coarse* } *buttery, melting, firm, breaking, crisp* juice { *little, medium, much* }

Flavor *acid, sub-acid, sweet* quality { *poor, medium* } *good, very good* *excellent, best*

Remarks

Specimens from Described by Date

Massachusetts Experiment Station Department of Pomology

FIG. 2.—Description blank for the fruit, with terms used.

	Inches.	Millimeters.
Very small,	Below $1\frac{3}{8}$	Below 35
Small,	$1\frac{3}{8}$–2	35–50
Below medium,	2–$2\frac{3}{8}$	50–60
Medium,	$2\frac{3}{8}$–$2\frac{3}{4}$	60–70
Above medium,	$2\frac{3}{4}$–$3\frac{1}{8}$	70–80
Large,	$3\frac{1}{8}$–$3\frac{5}{8}$	80–95
Very large,	$3\frac{5}{8}$–$4\frac{1}{4}$	95–110
Extremely large,	Over $4\frac{1}{4}$	Over 110

The measurements in inches are not in all cases exactly the same as the corresponding ones in millimeters, but it seems wiser to adhere to the use of less complicated fractions, even at a slight sacrifice of accuracy. The Siberian crabs should be considered in a class apart, and the above measurements will not hold for them. Probably most pomologists would give some consideration to the axial diameter in connection with size, but it is certainly of less importance than the cross diameter, and it would seem that the minimizing of such consideration would render descriptions simpler and more exact. The relation of the two diameters is brought out clearly in the description of form. Some varieties will run quite uniform in size, while others are more or less variable. This may be appropriately described under uniformity in size.

Form. — Pomologists are agreed that the form of a variety is most important, and therefore it should be described with care. In the present outline, under the term "form," is described only the general form of the fruit, leaving some of its divisions for consideration under the subheads. The form may be described as *oblate, globose, ovate, conic, oblong* or *truncate.* It is commonly said that an apple is oblate when the axial diameter is less than the cross diameter, and this is amply true; but when it is further said that in a globose apple the two diameters are equal, it is not true, if the actual measurement of the apple is considered. It may appear so to the eye, but owing to the indentation of the cavity and basin the cross diameter of such an apple is much the greater. Where the two are equal the apple would often be called oblong. For the reason given above the impression through the eye, which sees the general outline of the apple only, ignoring the flattening of the base and apex, and the actual measurement are unlike. The term "roundish" is commonly used instead of globose, but to us the latter seems the more exact and desirable term. The use of combinations of the terms given, such as *oblate-conic,* and of qualifying adverbs is often desirable and helpful.

After describing the form of the apple as a whole, special consideration is given to the base and the apex, the former comprising about one-third of the stem end, and the latter about one-third of the blossom end, of the apple. Each of these may be *conic, narrow, rounded, broad* or even *flattened.*

The cross section should be taken midway between the ends of the apple and at right angles to the axis. Two questions are to be answered under this heading — the first, whether the general outline approximates a circle, in which case it is said to be *round,* or if the apple is compressed, when the cross section will be *oval;* the second question is whether the outline is *regular, irregular* or *pentagonal.* Commonly, one cheek of an apple develops more fully than the opposite one, due apparently to better exposure to the sunlight, in which case the sides are said to be more or less *unequal.* As with size, we may find much or little uniformity in form within a variety. If a single specimen is being described no entry can, of course, be made under uniformity.

Color. — In the description of color a sharp distinction ought to be made between the greenish or yellowish ground color and the reddish over-color, for they are entirely different in their nature and significance. The former, designated simply as color, is some shade of *green, yellow* or, rarely, almost *white;* the latter is generally defined as some sort of *red,* either as *light* or *dark,* though some may prefer to consider red as a generic term and use in description such terms as *scarlet, crimson,* etc. The amount of over-color should be stated in the percentage of surface covered, and if more than one specimen is considered two numbers should be given, one representing the poorest and the other the best colored specimens. The disposition of the color is likely to be characteristic. It may be evenly spread over the fruit, in which case it is said to be *blushed,* or it may be unevenly disposed, *streaked, striped* or *splashed,* according to whether the markings are long and narrow, extending over nearly the whole cheek of the apple, of medium length or short and broad. Combinations of streaks, stripes and splashes often occur, and almost always with one or more of them there is interspersed other coloration that may be disposed irregularly and is said to be *mottled,* so that often an apple is *striped, splashed* and *mottled,* and on the sunny side the color may deepen to a *blush;* that is, the stripes and splashes are obscured by the higher development of color over the whole cheek. In naming colors or kinds of distribution it is best to always give them in order of abundance, giving the prevailing kind first. Russet may appear over the whole fruit or in the cavity only. In the latter case it finds mention under cavity markings, while in the former case it is described under russet as *dense* or *thin,* or it may be *irregular,* especially if it is not normal, but the result of unfavorable environmental conditions.

Bloom. — The amount of bloom is best ascertained by scraping the surface with a sharp knife, and recorded as *much* or *little* and the kind as *waxy* or *greasy.*

Skin. — The judgment of the observer of the thickness of the skin, whether *thick, medium* or *thin,* and the toughness, whether *tough, medium* or *tender,* are to be recorded under the proper heads. Under "surface" we note whether it is *smooth, rough* or *lumpy,* and whether it is *shining* or *dull,* also the presence of one or more *suture lines*, and the presence and nature of a *scarf skin*.

Dots. — The dots are often characteristic and valuable in description or identification. They are always found, and the first question is whether they are *conspicuous, distinct, inconspicuous* or *obscure*. This depends on several factors, such as number, size and color, so we proceed to describe these in turn. The number may be *many, few* or *scattering*. Their size may be *minute, small, medium* or *large*, also the size may be uniform or variable, so that they may be said to be *uniformly large* or *small* to *large*. The form of the dots may be *round, oval, angular, stellate* or *areolar*. Their color may be *white, gray* or *brown*, and the distribution *uniform*, or they may be more or less centered upon the apex of the fruit. Under "prominence" is stated whether they are *raised, even, sunken* or *submerged*.

Cavity. — Under "cavity" we describe first the depth, whether *deep, medium* or *shallow*, then the breadth, whether *wide, medium* or *narrow*, next the sides, whether *abrupt, steep* or *flaring*. The vertical outline, described as *acuminate, acute* or *obtuse*, is practically a repetition of the description of the side, and perhaps one of them might be omitted without loss. If so, we would prefer to retain the former, though the terms given under vertical outline are probably more commonly used. Under "cross section" is given the outline of a section taken about midway of the cavity. It may be *round* or *oval, triangular, pentagonal* or *irregular*. If it has a fleshy protuberance known as a lip it should be here stated. The presence of *russet* should be noted under "markings," and if the russet is *stellate* or *spreading* beyond the cavity it should be mentioned.

Stem. — Following the description of the cavity we naturally consider the stem, — the length, whether *long, medium* or *short*, and the size, whether *stout, medium* or *slender*, also if it is *clubbed*. Next we come to its direction in relation to the axis of the fruit. If it lies in the same line it is *straight*, and if not it is *inclined*, in which case it may or may not be *curved*. Next we have the color, usually some shade of *brown* or *green*, and the surface, which is *smooth* or *pubescent*.

Basin. — In the description of the basin much the same terms may be used as with the cavity, but it should be noted that the basin is formed differently from the cavity, so that the descriptive terms have a different significance, that is, the basin is always much broader at the bottom, more obtuse, and generally more shallow than the cavity. Some additional terms may be required in describing the cross section, such as *wavy, ribbed* or *folded*. The basin is rarely if ever russeted unless the whole fruit is russet, but occasionally we find a variety that is *leather cracked*.

Calyx. — Under "calyx" it should be stated whether it is *open* or *closed*, then follows the size, *small, medium* or *large*, and the surface, whether *smooth* or *pubescent*. The last is perhaps not an important point, as no marked differences between varieties are likely to be found.

Calyx Segments. — After describing the calyx as a whole we consider the individual segments, — their size, *small, medium* or *large;* their form, whether *obtuse, acute* or *acuminate;* and finally their position, whether *connivent, convergent* or *reflexed.* In some varieties, especially in over-developed specimens, they are *separate* at the base.

Tube. — The description of the calyx completes the exterior of the apple, and we come next to the interior, considering first the morphological characters exhibited. The tube length may be *short, medium* or *long,* the breadth *wide, medium* or *narrow,* and the form *conic* or *funnel-form.* The last term is an awkward one, but we can suggest none more suitable. The stamens are *basal, median* or *marginal,* according to whether they are near the inner end of the tube, in the middle or near the outer end. In describing the position of the stamens, only the broad or outer portion of the tube is considered; the narrower inner portion, which makes the tube funnel-form, should not be considered. Thus, "stamen position basal" means near the base or narrow end of a conic tube or of the broad portion of a funnel-form tube. The fleshy base of the pistils often persists, especially in specimens not thoroughly matured, and is noted as *present* or *absent.*

Core. — There seems to be some uncertainty as to the exact meaning of the term "core" as used by different systematic pomologists. We prefer to use it to indicate that portion of the fruit within the core lines. The first space in the blank shown is to describe the relation of the core to the axis of the fruit. If there is no space along the axis, and the axial border of the cells is straight, the core is said to be *axile,* while if the axial border of the cells is curved, so as to leave an oval or spindle-shaped space, the core is said to be *abaxile.*

Next is stated the size of the core relative to the size of the whole fruit, as *small, medium* or *large,* and then the position, — *sessile* if near the stem end of the fruit, *median* if in the middle, and *distant* if near the blossom end. The form of the core, as indicated by the course of the core lines, usually follows closely the outline of the fruit as a whole, and may be *oblate, oval, roundish, ovate* or *oblong.* Under "core lines" is described their relation to the calyx tube, which may be, rarely, *distant,* more commonly *meeting* or *clasping.*

Cells. — The cells are usually five in number, and the first point considered is whether they have an opening on the side toward the axis of the fruit; if so, they are *open;* if not, they are *closed.* Their size should be considered in relation to the size of the core as above defined, and they may be *small, medium* or *large.* If they are of similar size and form they are *symmetrical,* and if not, *unsymmetrical.*

Carpels. — The term "cells" signifies the space enclosed by the carpels, while the latter term means the horny walls, and each carpel is to be considered as a modified leaf. The form of the carpels is likely to be related to that of the core and of the whole fruit. They may be *elliptical, oblong, ovate, cordate, roundish* or *obovate.* The apex calls for especial consideration, and may be *acute, obtuse, mucronate* or *emarginate.* The surface toward the cell may be unbroken or *entire;* it may be marked by transverse fissures or *slit;* or these slits may be covered with a velvety growth, in which case the carpels are said to be *tufted.* The concavity of the halves of the carpels may be *little,* giving a small, thin cell, or it may be *medium* or *great.*

Seeds. — The number of the seeds may be stated as *few, medium* or *many,* and it is always desirable in careful work to give the exact number of seeds. Their condition may be *plump, medium* or *shriveled,* and their size *small, medium* or *large.* Size of seeds should be considered independent of the size of the fruit, and, as elsewhere stated, if the dimensions, preferably in millimeters, are given, it will contribute to the definiteness of the work.

The color of the seeds should be taken only from thoroughly ripe seeds, and is usually some shade of *brown, olive* or *gray.* The cross section, taken through the largest part of the seed, may be *roundish, oval* or *flattened,* while the longitudinal section, taken flatwise of the seed, may be *long* or *short;* also it may be *obtuse, acute* or *acuminate.*

Axis. — Axis length is considered in its relation to the size of the apple, and therefore is related to form and the depths of the cavity and basin. It may be *long, medium* or *short.* The direction is usually *straight,* but occasionally, and usually in the York Imperial, we find the axis *inclined.*

Flesh. — The flesh color is commonly *white* tinged more or less with *yellowish* or *greenish,* and it may be stained in certain parts with *pink* or *crimson.* The texture of the flesh is a very important factor, and may be described as *fine, medium* or *coarse;* also as *buttery, melting, breaking, crisp* or *firm,* the terms being arranged in order. A buttery texture is found only in those apples that break up and dissolve most readily in the mouth, while those with a very firm texture are usually not thoroughly ripened and break up only with some difficulty.

The juiciness of the fruit deserves special mention. It may be *little, medium* or *much.* It may be well to state that juiciness has no relation to the amount of water in the fruit.

Flavor. — Flavor and quality should be sharply differentiated, the former being due largely if not entirely to the relative proportions of sugars, acid and flavoring oils contained in the apple. It may be *acid, subacid, sweet,* according to the ratio of sugars and acid. The presence of an abundance of flavoring oil lends the quality often described as aromatic, but as aromatic relates to odor we prefer to use the word *spicy,* together with appropriate modifying adverbs, where the presence of flavoring oils is evident.

Aroma. — The aroma of an apple is often a means of identification, and it may be described as *none, faint* or *distinct.* If present it may be further described as *pleasant,* or special terms may be devised to suit the peculiar need.

Quality. — The term "quality" is used with a variety of meanings. In this bulletin it is meant to express the summation of the desirability of the apple for human consumption for table or kitchen use, as the case may be. Furthermore, it is the expression of the personal opinion of the individual describing it, and therefore it varies with different persons. There is no fixed standard for describing quality, and one person's opinion is as good as another's, provided his experience is as wide and his judgment equally sound. Quality is described as *poor, medium, good, very good, excellent* and *best*. The judgment of pomologists has been so charitable that "good" has come to signify that the apple under consideration is really rather poor and hardly desirable from the standpoint of quality; the other descriptive terms are similarly reduced from the meaning they have in common parlance.

In most cases one will hardly care to make such extended and minute descriptions as contemplated in the outline discussed above. Where a briefer description is sufficient, and for the student who has mastered these details, a briefer outline may readily be prepared; such briefer description will usually give for each variety those qualities which are characteristic and distinctive of that variety.

The Use of Quantitative Terms.

Where one wishes to do exact work it will increase accuracy to make liberal use of exact measurements; for the novice, especially if he be a student in systematic pomology, it will improve the soundness of his judgment in description, and therefore add to the value of his course of instruction. It takes time and cannot always be undertaken.

Many measurements of the tree characters may be made without difficulty. The height and spread of the tree may be ascertained by direct

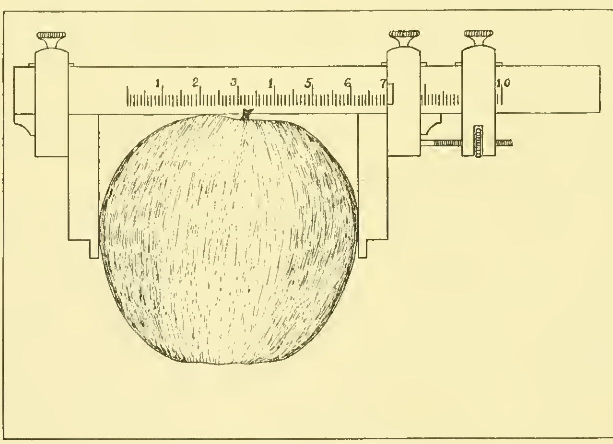

FIG. 3. — Measuring cross diameter.

measurement if the tree is small, or by any of the usual methods of forestry work where the tree is large. The length and diameter of the shoots and buds are easily measured; also the length of the petiole and the length and breadth of the leaf blade. The size of the serratures is most conveniently measured by counting the number per half inch or per centimeter.

An apple fruit seems rather an awkward body to measure accurately; nevertheless, by the adoption of certain fixed rules much can be accomplished. The instruments needed may be a simple ruler, preferably of celluloid, but a pair of calipers is often useful. The unit of measure may be the millimeter or the inch. In itself the former is much to be preferred, but the latter is more commonly used among American pomologists, and doubtless to them conveys a more definite meaning.

The most common and useful measures are the cross and axial diameters. The former should always be taken at right angles to the axis, and the latter parallel with it, and for the sake of a uniform practice it is best to secure the greatest diameter in each case. Calipers are necessary for exact

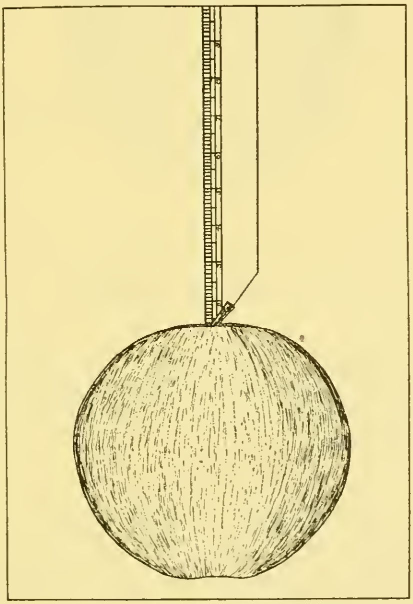

Fig. 4. — Measuring cavity depth.

work, but close approximations may be secured by placing the apple between two parallel surfaces, such as stiff cardboard or a pane of glass and a smooth table top. Of course, if the apple may be cut longitudinally the diameter may be quickly ascertained with a ruler. Care should be taken to cut so as to give its diameters at their longest.

The depth and breadth of the cavity and basin may be measured without cutting the fruit, as shown in Figs. 4 and 5. The rule should be whittled to a dull point about 2 millimeters broad, and the depth ascertained by sighting across the base or apex of the apple, as the case may be. In measuring the breadth the distance between the points of contact of the rule and surface of the fruit is taken. In both cases it is best to take the measure in the deepest and broadest part of the cavity or basin.

There are several characters in the interior of the apple that lend themselves readily to exact measurement. The length and breadth of the tube and of the core, as defined in the text, may be easily measured on cutting the apple longitudinally through the axis; also the length and breadth of

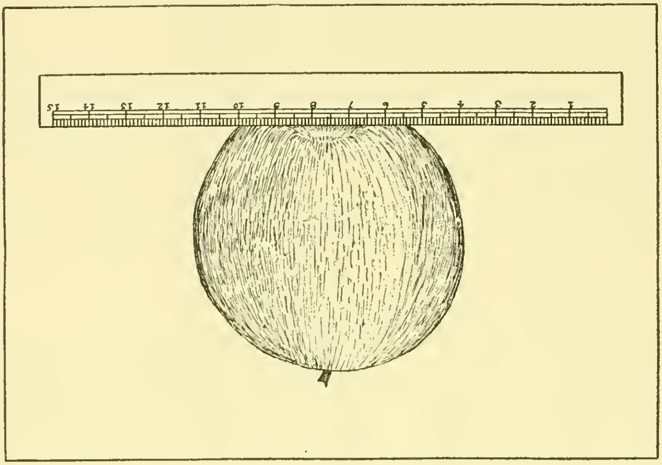

FIG. 5. — Measuring basin width.

the cells, making sure that the cut is made so as to split the cell exactly. The seeds are readily measured, giving their length, breadth and possibly thickness. The axis length from the insertion of the stem to the pistil point is easily measured.

THE COMMERCIAL DESCRIPTION.

A commercial description is quite a different thing from a systematic description. Many systematic characters are included, but their relative importance is changed, and many not mentioned in a systematic description are of the utmost importance. A commercial description of a variety can be made only after a long study of its behavior under varying conditions. Indeed, it would not be too much to say that we possess the knowledge needed for a fairly satisfactory commercial description of only a few varieties, and of these few there is much yet to be learned. Inasmuch as trade conditions are constantly changing, so must the commercial description be amended from time to time.

On the opposite page a blank for making a commercial description is suggested. The size, form and vigor of the tree are to be described as in the case of a systematic description. Under "diseases" should be mentioned such diseases as the variety in either tree or fruit is especially susceptible or resistant to, and so far as possible the degree of susceptibility or resistance. The same applies to the relation of the variety to various insects.

Variety

TREE

Size   Form

Vigor

Diseases

Insects

Climatic adaptations

Soil adaptations

Cultural methods

Productiveness, earliness   regularity

amount

Nursery growth

FRUIT

Size   uniformity

Form   uniformity

Color   over-color

disposition   amount

Skin   Cells

Flesh, color   texture   juice

Flavor   Aroma

Quality

Keeping quality   Shipping quality

Market value

Remarks

Described by   Date

Massachusetts Experiment Station   Department of Pomology

FIG. 6. — Blank for commercial description.

Under climatic adaptations we may indicate the conditions of climate under which the variety succeeds best, or, what is simpler, name the region where the variety flourishes best and attains its highest excellence. Under "soil adaptations" should be given the type of soil and subsoil which offers conditions for the best development of the variety.

Comparatively little has been said about the different methods of cultural treatment suited to different varieties; we are not yet beyond argument over soil treatment for all varieties collectively. Yet who can doubt that varieties differ in this as well as in other respects, and that the ideal cultural treatment for one variety may be quite wrong for another sort. Space for this discussion is provided in the blank, and with the accumulation of knowledge along this line it should find expression therein.

The productiveness of a variety is most important, and space is provided for stating if the variety comes into bearing *early* or *late*, and if possible, the age at which it may be expected to begin to bear commercial crops. Under "regularity" is stated whether it is *annual*, *biennial* or *irregular* in its bearing habit, and under "amount," whether it is a *shy*, *light*, *medium*, *heavy* or *very heavy* bearer. Productiveness, as well as the characters of the fruit given later, depends greatly on the conditions of growth under which the trees find themselves. If we are making a generalized commercial description, it is supposed that the description given is for the variety when growing under conditions of climate, soil and culture favorable to its complete and most satisfactory development. Under nursery growth is given any marked characteristics of the variety as it grows in the nursery row. The behavior of a variety in the nursery has often been the determining factor in its success or failure. Under fruit the various characters are to be described in practically the same way as in the case of a systematic description, but only those characters that are of marked commercial value find space here. We have added the characters of keeping and shipping quality which may be appropriately described.

The market value of a variety is the final test of its commercial worth. Here should be stated the suitability of the variety to the local or general market, and if the latter, the attitude of the great markets of the world toward the variety should find mention.

FIG. 7. — Baldwin × ⅔. Folded, even, straight or slightly reflexed, rather sharply serrate; the serratures strongly forward, often curved, medium size, generally rather deep, not distinct. The peculiar boat-shaped folding and curved, close-set serratures serve usually to identify the Baldwin.

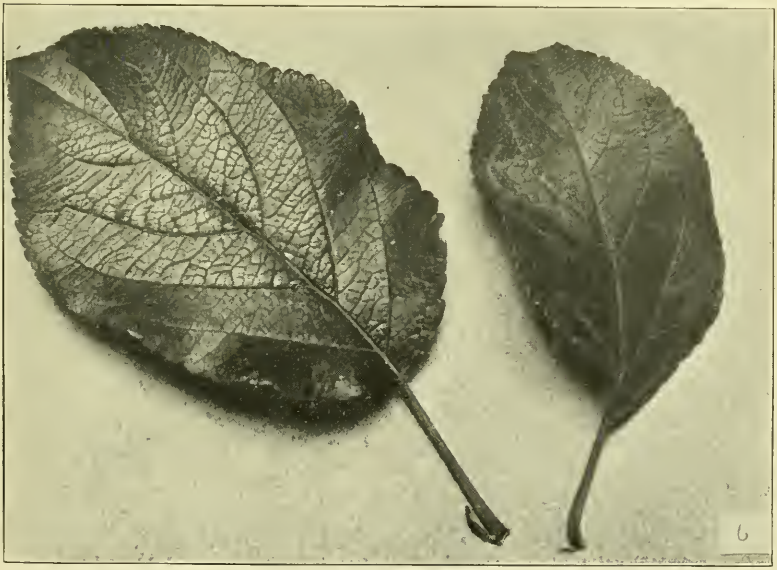

FIG. 8. — Wealthy × ⅔. Slightly folded, sligntly reflexed and waved. Very dull serrate or crenate; serratures forward, rather small, medium regular, not curved. The Wealthy is distinguished by its waved leaf, dull serratures and rather coarse texture.

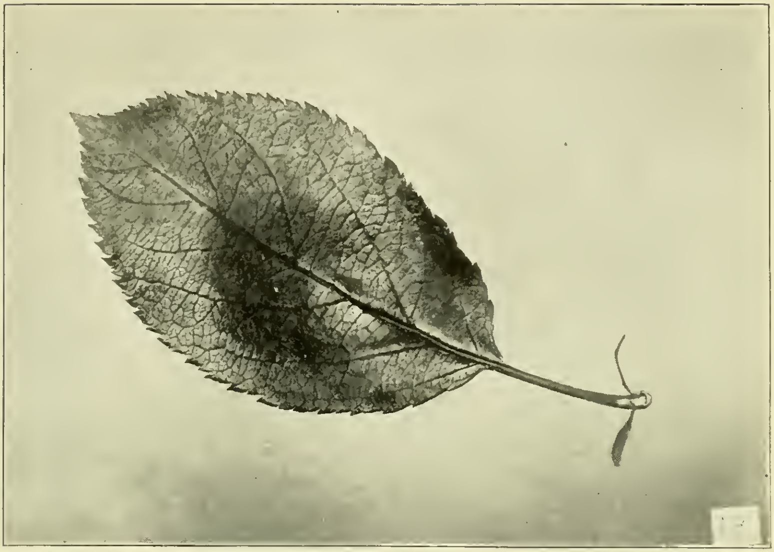

FIG. 9. — Rhode Island Greening × ⅔. Flat, straight or reverse curved, almost even, sharply serrate; serratures well forward, large, irregular, often tending to doubleness, not curved, deep and distinct. The sharp, distinct serratures are useful in identifying this variety.

FIG. 10. — Jonathan × ⅔. Very small, strongly folded, sometimes reflexed, waved, dull serrate; serratures well forward, medium or rather small; irregular, often curved, shallow, rather indistinct. The small size, dull serrations, soft texture and strong folding serve to distinguish the Jonathan.

Fig. 11. — Ben Davis × ⅔. Small, folded, somewhat reflexed, waved, dull serrate or crenate; base narrow; serratures moderately forward, small, quite regular, somewhat curved, shallow. Ben Davis may be known by its distinct waving, narrow base and dull, shallow serratures.

Fig. 12. — York Imperial × ⅔. Medium size, partly folded, reflexed, nearly even, dull serrate; serratures forward, large, irregular, rather deep, quite distinct. York Imperial may be known by its peculiar dull serrate, partly folded, spreading leaves.

Fig. 13. — Hubbardston × ⅔. Small, folded, strongly reflexed, somewhat waved, dull serrate; serratures slightly forward, rather small, fairly regular, moderately deep, distinct. Hubbardston leaves may be known by their small size, peculiar dull serratures, folding, strong reflexion of the midrib and peculiar gray color.

Fig. 14. — Northern Spy × ⅔. Partly folded, slightly reflexed, waved, serrate. Serratures well forward, medium or below, fairly regular, slightly curved, rather shallow, quite distinct. Northern Spy leaves not are easy to distinguish from several related varieties. Their peculiar folding, rather sharp serration and narrow apex serve to distinguish them from most varieties.

REPORT OF CRANBERRY SUBSTATION FOR 1914.

BY H. J. FRANKLIN.

The year's investigations have been along lines previously followed, except that the work with bees was discontinued and studies of the seasonal development of the cranberry root system and of the passage of water through peat were begun.

Weather Observations.

Records of conditions at the station bog were made as in previous years, and minimum temperatures at other locations were also recorded, together with whatever scattering data seemed to be of interest. The readings of the maximum and minimum shelter and bog thermometers and the amounts of precipitation were telegraphed to the office of the United States Weather Bureau at Boston during the periods of frost danger. Thermometers for taking soil temperatures were obtained, and records of those temperatures and their changes under different conditions were begun. The cranberry growing season as a whole was a cool one, there being more frost than usual, especially in September, and also much cloudiness throughout the summer. This caused the crop to ripen fully two weeks later than usual.

The total precipitation was distinctly below normal in spite of the unusual amount of cloudiness, and the beginning of the frost period in September found the ground rather unusually dry. The first cold night came on September 9, and was followed by nine others in succession. On some of these nights the minimum temperature at the low land thermometer near the station bog was 22° below the early evening dew point. Never before, by several degrees, had the station records shown any such difference under such general weather conditions. In the opinion of the writer, this extremely low temperature in comparison with the dew point was due mainly to an unusual lack of moisture in the ground. The difference between the minimum readings of thermometers on the station bog and on low land immediately adjacent was only 2° on the night of the 9th, and there was no difference the following night (10th). The temperatures were not compared on the 11th and 12th, the bog being flooded. On the 13th, the low land ran 6° colder than the bog minimum. As the bog was flooded again on the 14th, the next comparison was made on the 15th, when there was found to be a difference of 5½°. Never before in the records of four seasons had there appeared such a difference in the minimum temperature of these two locations unless the bog was flooded, — a fact which seemed to require explanation. As this difference did not occur until after the bog had been reflowed (no reflowing whatever had been done between June 26 and September 11), it seems probable that the effect of the flooding partially remained with the bog in some way in nights following those in which the flowing was done. Before the flooding, both the sand of the bog and the adjacent low land were unusually dry. The flooding left the bog in a condition of normal moisture, while the low land remained abnormally dry. This was apparently all that could have had any effect on the difference in temperature between the two locations. It seems evident, therefore, that moisture in the soil tends to maintain a higher air temperature above it on cold nights than would be had without it. That this is true is borne out further by the records of the latter part of September and the first part of October. On the 16th, the difference in the minimum temperature of the two locations — above mentioned — was 4½°; on the 17th, 3° (possibly so little because of failure of one thermometer to record properly); on the 18th, 4°; on the 20th, 6°; and on the 30th, 5°, these dates being selected because their nights alone were cold. Before any October records were made, over half an inch of rain fell, which, of course, did much to bring the soil of the low land back to a normally moist condition. After this rainfall the difference in the minimum temperature between the bog and the low land ranged from 1½° to 3½°, being distinctly less than it was before the rain came.

Acting on the suggestion obtained from these observations, that an increased water content of the soil tends to raise the minimum air temperatures above it on cold nights, the writer had two circular grassy areas (of between 2 and 3 square rods each) covered to an average depth of 6 inches with as dry sand as could be obtained in any quantity, between September 20 and 25. A Green minimum thermometer was placed over the center of each of these areas. On the nights of both September 26 and 27, these thermometers showed a difference of half a degree in their minimum readings. On September 28, the spot which had showed the lower minimum temperature on the two previous nights was wet down thoroughly with water, the wetting being done between 10 A.M. and 2 P.M., the temperature of the water used being 51° (pumped from a driven well 22 feet deep) and that of the sand on the other spot ranging from 51° to 52° at noon. The temperature of the air 6 inches above the center of the spot not wet down was 52° at 11 A.M., and that of the water in the ditches of the station bog at the same time ranged from 53° to 55°. In the cold nights following soon after, the thermometer over the spot that had been wet down recorded a minimum temperature from half a degree to a degree higher than the other one, the result of the test thus corresponding in a general way to that of the observations in connection with the bog and low land thermometers. Great reliance, however, cannot be placed on this result because of the small size of these test areas.

While the results of this investigation are not conclusive, they raise a question of no little importance, for if the moisture content of a soil affects the minimum temperatures of the air above it to any considerable extent, it is a factor that should be considered in making frost predictions in connection with the growing of cranberries and possibly of other crops also. It should be noted, however, that the results here discussed are at variance with those obtained by Prof. H. J. Cox on the Wisconsin marshes ("Frost and Temperature Conditions in the Cranberry Marshes of Wisconsin," by Henry J. Cox, 1910, Bulletin T. of the Weather Bureau, United States Department of Agriculture, page 61). Professor Cox shows that in comparative studies he obtained the lower temperature readings over the soil containing the greater amount of moisture and states that the increased moisture was "solely responsible for the relative low temperature readings, on account of the heat lost in the evaporation of the surface." The greater specific heat of water, as compared with dry earth, should not, however, be lost sight of in considering this matter.

Frost Protection.

Experiments with cloth, such as is used in growing tobacco under shade, were carried out in September, to see if it could be used satisfactorily in protecting bogs from frost. In these tests a strip of new cloth was supported by wires held 3 feet above the ground by stakes, about 9 square rods of rather dry, grassy low land being covered in this way, the cloth being brought down to the ground to shut in the covered area on all sides. The cloth was spread out for the tests after sundown on cold nights, and was always removed soon after sunrise, so that the ground might be normally exposed to the heat of the sun during the day. Considering the very coarse weave of the cloth, it retarded the rise of heat from the ground to a surprising extent, evidently because the heavy dew that accumulated on it closed its openings considerably. A Green minimum thermometer was placed at the center of the covered area, with its bulb 5 inches above the grass-covered ground, and a similar thermometer at the same elevation, located over grass about 20 feet outside of the cloth, was used for comparison. No frost formed on the covered ground during the tests even when the surrounding low land was white with it, and the thermometers showed that the cloth gave an advantage of more than 4½° in temperature, as shown by the readings in the following table: —

Table 1. — *Effect of Cloth Cover on Temperature.*

Date.	Minimum Temperature (Degrees Fahrenheit).		Wind Velocity (Miles per Hour).
	Area 1.	Area 2.	
September 13, ...	Covered, 31, . .	Not covered, 26½, .	1½ to 4
September 14, ...	Covered, 31, . .	Not covered, 26½, .	6/7 to 1
September 15, ...	Covered, 30⅔, . .	Not covered, 26½, .	⅗ to 1 5/7
September 16, ...	Not covered, 29¾, .	Not covered, 30½, .	No record.
September 17, ...	Not covered, 32⅓, .	Not covered, 32¼,[1] .	No record.

[1] This reading was unusually high, as compared with that over "Area 1," as was shown by numerous readings of these thermometers observed later, but not recorded.

The difference in temperature caused by the use of the cloth might have been greater had a larger area been covered, but the advantage shown in the table would be sufficient to entirely protect a bog in most locations, except under such extreme conditions as would only rarely occur, and even under such conditions it would afford a partial protection. The results of the tests, therefore, appear to highly recommend the use of this cloth for frost protection on bogs which are winter flowed but cannot be reflowed in any way at reasonable expense. It can be purchased in quantity from the manufacturers, all sewed up in strips of any desired size, for 3⅛ cents per square yard, the cost of enough for a whole acre being only about $150, and, if properly cared for, it ought to give good service for many years, as it would seldom be used for extended periods. When used to cover a whole bog, it would have to be spread out on wires in sections and be so arranged that considerable areas could be either covered or uncovered by a single pull of a rope. The first cost of this means of protection fully installed probably would be less than $200 an acre, and the loss by depreciation would be no greater than the cost of the upkeep and operation of a pumping plant. If a grower had to install his protection at less cost than this, he probably could do so by buying cloth that had been used one season in growing tobacco. In the opinion of the writer, the protection afforded by new cloth would be as good as that which would be had with a pumping plant, for such plants frequently fail in emergencies. For strictly dry bogs (without winter flowage) the expense of cloth protection seems prohibitive, because the returns from such bogs are comparatively small.

Fungous Diseases.

These studies were carried on, as in former years, in co-operation with the Bureau of Plant Industry of the United States Department of Agriculture, Dr. Shear having general supervision of the spraying experiments and conducting the laboratory investigations.

Of the various sprayed plots, results with which have been given in previous reports, the following were treated again with Bordeaux mixture on dates as indicated, the neutral copper acetate application given in former years being omitted: A, three times, on June 16, July 20 and August 7; B, three times, on June 16, July 20 and August 8; D, three times, on June 13, July 20 and August 13; "1913," three times, on June 16, July 27 and August 17 (an extra spraying was applied during full bloom to one-half of this plot on July 11); one-half of fertilizer plot 15, three times, on June 16, July 20 and August 8. Plots C and E were left without treatment. The middle half of plot A was fertilized on June 18, a quarter of the plot on each side being left without fertilizer as in the previous season, that used on the middle portion being applied at the following rate per acre: —

	Pounds.
Nitrate of soda,	200
Acid phosphate,	400
High-grade sulfate of potash,	200

The following table shows the total amount of fruit picked from these various plots and from check areas measured out on the bog adjacent to them, as well as the rate of yield per rod in each case, the relative size of the berries, and the per cent. of increase or decrease in fruit production of the plots as compared with their checks: —

TABLE 2. — *Results of Spraying for Fungous Diseases.*

PLOT.	Area of Plot (Square Rods).	Variety.	Date picked.	Quantity of Fruit obtained (Bushels).	Quantity of Fruit per Square Rod (Bushels).	Decrease or Increase on Plots (Per Cent.).	Average Size of Berries and Number of Samples examined.
A (middle portion), .	8	Late Howe, .	Sept. 26	9	1.125	23.5[1]	90+3 (6)[2]
A (side strips), .	8	Late Howe, .	Sept. 26	9⅔	1.208	17.8[1]	96+4 (10)
A (3 checks),[3] . .	17½	Late Howe, .	Sept. 26	25⅔	1.470	–	94+4 (5)
B, ...	14⅛	McFarlin, .	Sept. 26	11½	.814	3.2[1]	72+2 (6)
B (1 check), . .	13⅔	McFarlin, .	Sept. 26	11½	.841	–	67+2 (6)
C, ...	16	Late Howe, .	Sept. 26	11⅔	.729	13.2[4]	97+4 (6)
C (2 checks), . .	9	Late Howe, .	Sept. 26	5⅘	.644	–	95+3 (6)
D, ...	16	Early Black, .	Sept. 16	14⅔	.917	3.85[4]	109+11 (6)
D (2 checks), . .	16½	Early Black, .	Sept. 16	14½	.883	–	103+8 (6)
E, ...	16	Early Black, .	Sept. 8	9	.563	10.9[1]	106+11 (6)
E (2 checks), . .	12	Early Black, .	Sept. 8	7 7/12	.632	–	103+5 (6)
"1913,"[5]	4½	Late Howe, .	Sept. 26	5½	1.222	38.39[4]	100+4 (6)
	4½	Late Howe, .	Sept. 26	6⅓	1.407	59.34[4]	100+5 (6)
"1913" (2 checks), .	6	Late Howe, .	Sept. 26	5 3/10	.883	–	100+3 (6)
Sprayed half of fertilizer plot 15, . .	4	Early Black, .	Sept. 16	5⅙	1.292	1.6[1]	104+8 (6)
Other half of plot 15,	4	Early Black, .	Sept. 16	5¼	1.312	–	106+6 (6)

[1] Decrease.

[2] The size of the fruit as shown in the above table was worked out by taking counts of the berries in cupful samples (New England Cranberry Sales Company's inspector's cup), the samples being spread out in a sales company's inspector's hand-grader before the counting was done. When placed in the grader the smallest berries would pass through into the box below, leaving the larger ones to be counted separately. In such formulas as "90+3," given in the table, the first figure shows the average number of large berries, and the second indicates the number of small ones that passed through the grader, the figure in parentheses being the number of samples examined. These samples were examined at the end of the storage tests, and were taken from different boxes as far as possible, so that they might fairly represent the areas from which the berries were picked.

[3] When two or more checks were taken on a plot, as the table shows was generally the case, they were laid out on opposite sides of the plot, and their areas and fruit production were combined in making up the table.

[4] Increase.

[5] The first record given for this plot is for the half sprayed in full bloom, and the other record is for the half which received the three other applications only.

It will be seen at once that, of all these plots, "1913" alone showed a marked increase in the quantity of fruit produced. This plot was sprayed for the first time in 1913, and the results obtained with it in this second year of spraying agree, in a general way, with those obtained in 1912 with plots A, B, C, D and E, they then having been sprayed only one year before. Moreover, the increase was marked, though considerably reduced, even on that portion of the plot which had been sprayed during full bloom. The reason for this increase in the second year of spraying is obscure, but the fact that it takes place is interesting. The fact that the sprayed half of fertilizer plot 15, which was also sprayed for the first time in 1913, did not show an increase in fruit production is contradictory, but the fertilizer used on this plot may have made the difference.

All the other plots treated this year, except D, produced less fruit than their checks, and D showed only a slight increase. The untreated plot C produced distinctly more fruit than its checks, while E showed a decrease almost as great; the results with these two plots thus being contradictory and not sufficiently marked to be of any apparent value. As all the plots produced much less fruit in 1913 than did the surrounding portions of the bog, they should all, under normal conditions, have shown a distinct increase in 1914 because of their partial rest from fruiting. That they did not do so is good evidence that the spraying was not particularly beneficial and perhaps indicates injury from it.

The smaller the berries the greater the number it took to fill the cup, and if the table is examined with this in mind it will be seen that all of the plots, except "1913," the sprayed half of fertilizer plot 15 and the middle portion of plot A, produced distinctly smaller berries than did their checks. The fertilizer accounts for the exception with plot A and probably also with plot 15; "1913," as already indicated, was an exceptional plot because of its having been sprayed only one season before 1914. The size as well as the quantity of the fruit on these plots seems, therefore, to indicate that general spraying is not a good practice.

The spraying on all these plots was done with a 30-gallon wheeled-barrel outfit, the mechanical injury to the vines not being very great as a long hose was used and the outfit was in no case taken onto either the sprayed areas or their checks. The berries were all picked with scoops and measured in selected boxes of approximately the same size, the loose vines being carefully removed by hand.

The keeping qualities of the fruit from these plots and their checks were tested, the period of storage extending from November 3 to December 30 with the late berries, and from November 14 to New Year's with the Early Blacks. As in the 1913 tests, the berries were carefully measured in every case. The results of these tests were not definite enough in any respect to be satisfactory, perhaps because they were begun too late or because the berries were run through a separator before they were placed in storage, this not having been done in previous years.

As already indicated, one-half of plot "1913" was sprayed during full bloom to determine whether Bordeaux mixture, made according to Dr. Shear's formula for its preparation for cranberry spraying, would do serious damage if applied at that time. The figures given in Table 2 show that this spraying did injure the blossom considerably, causing a reduction in the crop of about 13 per cent., if we regard the bloom as having been equally abundant on both halves of the plot. As a matter of fact, however, the more heavily blossomed half was purposely selected for this special spraying, and the reduction caused by it, while not definitely computable, was certainly much greater than the figures show.

Tests of the possibility of controlling fungous diseases by putting copper-sulfate in the flowage were again carried out this year, a solution of the chemical being used in the June reflow on flooding sections 23, 25 and 27 at the rate of 1 part to 50,000 parts of water (1 pound in 6,250 gallons). The treatment was applied after these sections had been completely flooded for seventeen hours, and the water was then held twenty-six hours longer. The sulfate solution was thrown into the water by the cupful and was distributed as evenly as possible over all parts of each section treated. The date of treatment was June 11. The blossom buds were then well developed and they did not seem to be injured by the treatment.

Both the treated and untreated sections were picked with scoops on September 7, the former showing no definite advantage in the quantity of fruit obtained. In the storage tests, however, the berries from the treated sections showed, in every case, a distinctly smaller percentage of loss than did those from the other sections. These results are exhibited more in detail in the following table: —

TABLE 3. — *Effect of Treatment with Copper Sulfate in June Reflow.*

Flooding Section.	Variety.	Area of Plot (Square Rods).	Quantity of Fruit picked (Bushels).	Quantity of Fruit per Square Rod. (Bushels).	Period of Storage.	Quantity stored (Bushels).	Loss in Storage (Per Cent.).
21, . .	Early Black,	21.30	13¼	.622	Nov. 14 to Jan. 1.	3	20.59
22, . .	Early Black,	5.10	2¾	.539	Nov. 14 to Jan. 1.	1	29.41
23,[1] . .	Early Black,	12.80	9⅓	.729	Nov. 14 to Jan. 2.	3	18.63
24, . .	Early Black,	5.00	3	.600	Nov. 14 to Jan. 1.	2	26.09
25,[1] . .	Early Black,	11.60	7⅓	.632	Nov. 14 to Dec. 30.	2	13.97
26, . .	Early Black,	4.50	2½	.555	Nov. 14 to Dec. 31.	1	34.00
27,[1] . .	Early Black,	10.66	7	.656	Nov. 14 to Dec. 31.	2	16.67
28, . .	Early Black,	3.08	1¼	.406	-	-	-
29, . .	Early Black,	10.61	8	.754	Nov. 14 to Dec. 31.	2	23.53

[1] Treated.

The reddened and sickly appearance of the foliage on most of the sprayed plots, mentioned in the report for 1913 (page 41), persisted more or less throughout the season of 1914, especially with the Late Howe plots, even where the spraying was discontinued this year. The reason for this apparent injury to the sprayed areas was carefully sought, the condition of the root systems of the sprayed and unsprayed vines being given particular study, as such an investigation seemed to promise the most ready solution of the problem. The roots were first examined late in May. It was soon found that new rootlets were developing in connection with the unsprayed vines all over the bog. On the sprayed plots, however, there was almost no new root development. It was also noticed early in the season that there was a rather scanty growth of old rootlets near the surface of the sand on the sprayed areas, while on untreated parts of the bog this growth was evidently much more abundant. Moreover, the rootlets near the surface on the plots appeared to be blackened and rather lifeless, as though injured by burning. In June and July the difference in the condition of the roots of the sprayed and unsprayed vines was rather striking. It could be most easily observed by grasping single vines between the thumb and forefinger, close to the surface of the sand, and pulling them up by the roots. When this was done, it was apparent at once that there was no considerable mass of rootlets on the sprayed vines for about an inch below the surface of the sand, while on those that had not been sprayed the rootlets were usually massed close up to the very surface. This condition of the roots seemed to suggest that they had been injured by the spraying in some way.

Attention is called, in this connection, to the fact that a New Jersey grower of large experience has informed the writer that he found his vines taking on a similar sickly, reddish appearance after he had been spraying his bog a few years. His vines apparently got into a worse condition than have those on the sprayed plots of the station bog, a considerable dying out taking place among them. The grower, however, laid the trouble to lack of proper plant nutrition, and applied fertilizers containing nitrates. His vines recovered, taking on a normal green appearance, and are now producing satisfactory crops again. His results in this regard seem to be paralleled — to a considerable extent — by those obtained on the station bog with plot A, the middle half of which was fertilized in both 1913 and 1914, as stated in another place. The vines remained green and thrifty on the fertilized part of this plot, while the unfertilized parts took on the reddened appearance that has been described. In both 1913 and 1914, however, the fertilized part of this plot failed to produce anywhere near as much fruit as did the surrounding unsprayed portions of the bog. While it is by no means certain that the New Jersey grower's difficulty was caused in the same way as that on the station bog, the comparison is certainly suggestive.

To get further light on this whole problem, and to determine definitely in what ways spraying with Bordeaux mixture does injury, special spraying experiments were started on small plots, the sprays applied being made up with varying proportions of lime and copper-sulfate, resin fish-oil soap being used with some and being left out with others. These sprays were applied in excessive quantities (25 gallons to the square rod) so that they would soak into the ground and come in contact with the roots thoroughly. If these experiments show that Bordeaux mixture necessarily causes considerable injury to cranberry bogs, general spraying for the control of fungous diseases on the Cape bogs will seem impracticable until some non-injurious substitute for the Bordeaux can be found. Doubtless, some bogs are occasionally so badly infested with fungous diseases that spraying would be advisable even if it did cause considerable injury. Diseases appear to be so much more prevalent in New Jersey than they are on the Cape bogs that spraying should probably be generally adopted there in spite of the possibilities of its doing damage.

The "ring-worm" trouble (commonly so-called by the growers because it was formerly supposed to be the result of some insect's work) was given some study. The vines die in a small patch at first and, the center recovering, the affected area gradually becomes circular. These patches persist for years, the vines on the outer side of the rim dying every season, while recovery takes place on its inner side, the circle thus growing larger yearly and preserving its form if not interfered with by a ditch or some other obstruction. Both Dr. Shear and the writer for some time have believed this trouble to be due to a fungous disease. Insects evidently do not cause it. This year evidence has come to hand which appears to go far toward proving that fungi are at the bottom of the trouble. On Sept. 24, 1910, the writer visited some bogs in Plymouth, belonging to Mr. Henry J. Thayer of Boston, and found them more badly marked with "ring-worm" patches than any other bog he has ever seen. Moreover, it had been with Mr. Thayer a trouble of long standing, for the "rings" varied in size from mere beginnings to circles 25 or 30 feet in diameter. He thought it was caused by some insect, but decided to try spraying with Bordeaux mixture on the chance that it might be a fungous trouble. He sprayed twice in 1911, three times in 1912, three times in 1913, and twice in the present year, before the writer visited his bogs again on July 4. The change since 1910 was very striking, the "rings" having in most cases entirely or nearly disappeared, and no new dying of the vines being apparent. Mr. Thayer thought his spraying had caused the improvement, and it evidently had. His results seem to help prove the character of the "ring-worm" trouble. It should be stated, however, that in all of his spraying after the season of 1911 Mr. Thayer used commercial "Bordo Lead" with a little Paris green instead of straight Bordeaux mixture.

Early in July, a North Carver grower sent in some vines seriously affected by an unfamiliar disease. Specimens were forwarded to Dr. Shear, and he found the trouble was one which had been known for a long time in Wisconsin, but which had never been previously reported from any other cranberry-growing section. The Wisconsin growers commonly call this disease "false-blossom." There is, however, an entirely different trouble known as "false-blossom" (hypertrophy caused by *Exobasidium* sp.) by the Cape Cod growers, and to distinguish between the two, the new disease will be called "Wisconsin false-blossom" in this report. It is characterized by an abnormally profuse branching of the vines and a peculiar abortion and malformation of the blossoms. The latter do not develop normally in size or color, but are small and greenish. The peduncles do not curve over naturally, but remain straight and become more or less swollen, so that the flowers open facing upward. The blossoms thus affected produce no berries, and the crop is often greatly reduced in quantity when the vines are badly infested.

The vines sent in affected with this trouble came from a bog on which "Metallic Bell" vines from Wisconsin were planted about ten years ago. The discovery of this disease in Carver led Dr. Shear and the writer to investigate its distribution. It was found on five bogs, all in North Carver, the source and center of trouble being evidently, in every case, vines which had come from Wisconsin. On four of these bogs the trouble centered around the "Metallic Bell" variety. The name of the variety causing the trouble in the fifth case is not known. On one bog the disease had apparently spread from the "Metallic Bell" vines and attacked those of the "Late Howe" variety, especially on some new planting, and was also found to some extent on "Nova Scotia Bell" vines. On another it seemed to have spread from the "Metallic Bell" variety to "Centreville" vines to a slight extent. It was least prevalent on the bogs which had usually been run dry during the growing season, those which had been kept wet being very badly infested. It was first observed on one of these bogs five years ago and has apparently been growing gradually and steadily worse. The discovery of the presence of this Wisconsin disease on the Cape may be a matter of much importance. It is evidently a serious disease, and the results of the season's observations strongly suggest that it may be infectious, though it has by no means been proved to be so. Until more is known about it, Wisconsin varieties cannot be planted on the Cape without considerable risk. The discovery of this disease in Massachusetts and the results of our investigation concerning it are especially interesting in the light of the observations regarding it recently published in the annual report of the director of the Wisconsin Agricultural Experiment Station.[1]

Observations in connection with the new disease, spoken of as the "blossom-end rot" in previous reports, have been continued. This disease was again this year the chief cause of decay among "Late Howe" berries in storage. Numerous samples of fruit infected with it were sent to Dr. Shear for laboratory investigation. Its exact place in botanical classification is not yet determined.

Resanding.

The experiments in resanding have been continued, five plots on the station bog having been devoted to this investigation since October, 1912. Two of these plots have not been resanded for six years. The other three have been resanded every year for the last four years. The bog as a whole

[1] Bulletin No. 240 of the Wisconsin Agricultural Experiment Station, June, 1914, p. 54.

was resanded in the fall of 1911 and spring of 1912 and again in the fall of 1914.

The results with these plots in the amounts of fruit produced were not at all conclusive. The results of the storage tests, however, with only one exception, agreed with those of former years in showing that resanding greatly favors fungous diseases.

Fertilizers.

Most of the fertilizer plots on the station bog were given their 1914 application on June 17 and 18. The lime was not applied to plot 11 until July 17, and plot 12 went without fertilizer until the same date because the muriate of potash was not delivered promptly. The plots were picked with scoops on September 16 and 17, no distinct advantage in quantity of fruit being shown by the fertilized areas as compared with the check plots. The berries seemed so uniform in color and most other respects that no records were made except of their quantity and size. Average counts of berries in several cupful samples taken from each of the plots did not show that the fertilizer had distinctly affected their size.

Storage tests, beginning November 14 and ending on New Year's day, were carried out with berries from each of the plots. These tests probably were not as reliable as those of former years because the berries were run through a separator before they were stored. The results, however, seem to show that the nitrate of soda distinctly impaired the keeping quality, though the greater shrinkage of the fruit from the nitrate-treated plots may have been due to a greater loss of water during storage, rather than to increased rotting, the berries perhaps being somewhat more succulent. The year's experience with these plots and their fruit is shown in detail in Table 4.

Plots 1, 5, 9, 13, 17, 21, 22 and 23 are all untreated check plots. The meanings of the fertilizer symbols used in the table are as follows: —

O = Nothing.
N = 100 pounds nitrate of soda per acre.
P = 400 pounds acid phosphate per acre.
K = 200 pounds high-grade sulfate of potash per acre.
L = 1 ton of lime (slaked) per acre.
Kcl = 200 pounds muriate of potash per acre.
$N_{1\frac{1}{2}}$ = 150 pounds nitrate of soda per acre.
N_2 = 200 pounds nitrate of soda per acre.
$P_{1\frac{1}{2}}$ = 600 pounds acid phosphate per acre.
P_2 = 800 pounds acid phosphate per acre.

In combination they mean, for example, as follows: N_2PK = 200 pounds of nitrate of soda + 400 pounds of acid phosphate + 200 pounds of high-grade sulfate of potash per acre.

TABLE 4. — *Effect of Fertilizers on Quantity and Keeping Quality of Cranberries.*

Plot.	Fertilizer used.	Date picked.	Quantity of Fruit produced (Bushels).	Quantity of Fruit in Storage Test (Bushels).	Loss in Storage (Per Cent.).
1,	O	Sept. 16	9	3	27.45
2,	N	Sept. 16	9½	3	31.37
3,	P	Sept. 16	8⅘	3	20.59
4,	K	Sept. 16	8	3	24.51
5,	O	Sept. 16	6½	3	26.96
6,	NP	Sept. 16	6⅔	3	34.00
7,	NK	Sept. 16	7⅔	3	31.37
8,	PK	Sept. 16	8⅔	3	23.53
9,	O	Sept. 16	6½	3	29.41
10,	NPK	Sept. 16	8⅔	3	33.00
11,	NPKL	Sept. 16	8⅙	3	37.25
12,	NPKcl	Sept. 16	7¾	3	28.43
13,	O	Sept. 16	7⅔	3	22.53
14,	$N_{1½}PK$	Sept. 16	10	3	24.51
15,	N_2PK	Sept. 16	10 5/12	3	26.96
16,	$NKP_{1½}$	Sept. 16	9	3	27.45
17,	O	Sept. 16	9⅔	3	23.04
18,	NKP_2	Sept. 17	10	3	30.39
19,	$NPK_{1½}$	Sept. 17	9	3	25.49
20,	NPK_2	Sept. 17	6⅚	3	31.37
21,	O	Sept. 17	10⅓	3	32.50
22,	O	Sept. 17	10⅘	–	–
23,	O	Sept. 16	6⅓	3	22.22

As some of the 1913 experiments had seemed to indicate that the setting of the blossoms was stimulated and increased to a considerable extent by the application of nitrogenous fertilizers during the beginning of the bloom, special tests to determine this point were conducted this year. Two plots of four square rods each — one "Early Black" and one "Late Howe" — were fertilized on July 3, the former variety being in full bloom and the latter needing about a week longer to reach that condition. The fertilizer was applied at the following rate per acre: 150 pounds of nitrate of soda + 400 pounds of acid phosphate + 200 pounds of high-grade sulfate of potash. The sand with which the fertilizer was mixed to insure even application stuck to the vines considerably, and it was feared that it might injure the bloom more or less, especially that of the more advanced early variety. The fertilizer was soaked into the bog by a storm which began at 6 P.M. on July 6, there having been no previous rainfall whatever since its application. The plots were examined on July 7, and the "Early Black" vines were then found to be somewhat past full bloom, those of the "Howe" variety having not yet quite reached that condition. Table 5 shows the results obtained with these plots. The size of the berries is indicated by the number it took in each case to fill the inspector's cup of the New England Cranberry Sales Company, two samples being averaged for the "Early Black" records and six for the "Late Howe." The smaller the berries the greater, of course, was the number it took to fill the cup, the sizes, therefore, being inversely proportional to the numbers given in the table: —

TABLE 5. — *Effect of Fertilizer on Setting of Fruit.*

PLOT.	Area of Plot (Square Rods).	Date picked.	Quantity of Fruit obtained (Bushels).	Quantity of Fruit per Square Rod (Bushels).	Increase (Per Cent.).	Average Size of Berries and Number of Samples examined.
Early Black, . . .	4	Sept. 10	3¾	.937	7.14	125 (2)
Early Black (check), .	4	Sept. 10	3½	.875	–	120 (2)
Late Howe, . . .	4	Sept. 28	6⅘	1.700	26.50	103 (6)
Late Howe (check), . .	8	Sept. 28	10¾	1.344	–	106 (6)

As the table indicates, there was a distinct increase in fruit on the "Early Black" plot as compared with the surrounding bog, though it was much less marked than that on the "Late Howe" plot, probably because of the difference in the development of the bloom when the fertilizer was applied. It will be seen at once that the increase in quantity was in neither case due, to any considerable extent, to an increase in the size of the berries, and that the fertilizer had apparently caused a greater number of blossoms to set and form fruit with both varieties. In storage tests there was slightly more decay among the berries from the "Late Howe" plot than among those from its check. The "Early Black" fruit was not tested in this regard.

INSECTS.

The insect studies have covered a rather wide range during the year. The flowed-bog fireworm (black head cranberry worm) and the fruit worm both seem to have been much less abundant than usual, the total injury caused by them probably being about the same as in 1913.

In May and June the forest tent caterpillar (*Malacosoma disstria* Hübner) was very abundant everywhere in the cranberry section, and the worms crawled onto the bogs in large numbers. Their operations were watched carefully, but they were never found feeding on the cranberry vines, and their presence on the bogs need never cause concern, for their normal food plants are evidently so different from the cranberry that the latter is not palatable to them.

Cape Cod, in common with many other sections of the country, suffered this year from a rather severe visitation of the army worm (*Heliophila unipuncta* Haworth). It did quite a little damage on bogs here and there, but the cases of great injury appear to have been few. The cranberry is evidently not a favorite food plant with this insect. It usually works on grasses, grains and corn. As it prefers low lying land, however, the moths frequently, in "army worm years," deposit their eggs in quantities on the bogs, and then the vines are attacked because of the absence or scarcity of grasses. Rarely, however, is a large bog seriously hurt on more than a few sections. The growers probably need not fear this insect in 1915, for it rarely appears in great numbers two years in succession, as its natural enemies soon control it.

The gypsy moth (*Porthetria dispar* L.) is becoming more of a menace every year. Numerous reports of threatening danger from it were received during the season of 1913, and this year it has caused no little damage on bogs in several localities. It is becoming more abundant yearly on the uplands around the bogs in much of the cranberry section. The danger to the bogs themselves, except possibly where water for reflowage is abundant, evidently grows greater in proportion to this upland increase, for while the female moths cannot fly onto the bogs to lay eggs the small worms can readily be blown on by the winds. This insect, therefore, is fast becoming a cranberry problem, and it must be given more attention from now on. The following matters in connection with it need to be determined especially: —

1. In the more serious cases of bog infestation, does the trouble arise from eggs laid on the bog the year before or from small caterpillars blown on by the winds early in the season?

2. Can gypsy moth eggs survive winter flooding, if the water is held until late in May? It is known that they can endure an ordinary winter flowage (until April 1). In case severe bog infestations usually arise from eggs deposited the previous season, knowledge concerning the limit of their ability to endure submergence becomes of prime importance.

3. What is the best time to reflow to destroy this insect? The caterpillars are very hairy and will float for a long time before they die. The larger they are the longer they can probably live in this way. For this reason a bog should probably be flooded as soon after the eggs hatch, or after the worms are found at work, as possible. The insect net which has been recommended for discovering the first stages of the false army worm probably would be useful in detecting the presence of the small gypsy moth caterpillars early in May. When a bog infested with this insect is flooded, the worms usually float ashore alive in large numbers, and must be killed by burning or by spraying with crude oil or kerosene.

The cranberry weevil (*Anthonomus suturalis* Lec.), which occasionally harms a bog by working within the blossom buds and eating out their hearts, thereby preventing blooming and fruiting, did much damage on some bogs in Plymouth in 1913, and also caused some loss in the same locality this year. Heretofore no effective treatment has been known for this insect. Attempts to destroy it by flooding have been uniformly unsuccessful. The results of some spraying done this year under the supervision of Mr. Henry J. Thayer of Boston, in anticipation of injury from this insect, are therefore interesting. Arsenicals ("Bordo Lead" with Paris green) were used while the vines were in bud, some time before any blossoms had opened. The bogs thus sprayed and adjacent unsprayed vines were examined in August. The weevil evidently had done much less damage where the spray had been applied.

The spanworm (*Epelis truncataria* var. *faxonii* Minot), discussed in last year's report (pages 50 and 51), was found to have seriously damaged a bog in Wareham. Growers of large and long experience in the vicinity, when shown these worms, expressed the opinion that this species was the one which used to be so commonly and widely injurious on the Cape bogs. If they were correct in this, as seems most probable, the name "Cranberry Spanworm," given by Dr. J. B. Smith to *Cleora pampinaria* Gn., is more deserved by this species. Caterpillars of this insect were collected on the infested Wareham bog on July 23, 1913. By August 8 many of these worms had pupated, and many pupæ of an Ichneumonid parasite were also found, from 25 to 30 per cent. of the worms apparently having been infested with it. The adult parasites emerged from their pupa cases on dates ranging from June 12 to June 27, 1914. They proved to be a dark-colored species of *Campoplex*, with a broad reddish band about the abdomen. This parasite is new to science, and its full description will soon be published by the writer elsewhere.[1]

The infested Wareham bog was visited again on May 28, 1914, and live pupæ of the spanworm were found under the vines in large numbers. The bog had been winter flowed in December, and the water had been let off on May 10, the pupæ thus having survived a five months' submergence. This confirms the observations in connection with this insect on the Yarmouth bog, where the entirely naked (that is, without any cocoon) pupæ endured flooding for more than four months with but a small percentage of mortality. No moths of this insect were observed on the Wareham bog on May 28.

The "tip worm," the "flowed-bog fireworm" ("black head cranberry worm") and the "fruit worm" are of such importance and so constantly troublesome that our investigations with them deserve special and detailed consideration.

The Cranberry Tip Worm (*Cecidomyia oxycoccana* Johnson).

In 1911, a serious dying of the tips took place on the station bog soon after the vines went out of bloom. Evidently largely as a result of this, the bog did not bud up well for the following season, and the small crop of 1912 (less than 200 barrels) was the result. Until this year the writer thought this tip trouble was secondary to some injury to the root system, caused, perhaps, by mismanagement in the use of water during the growing season. This idea seemed to be substantiated by the fact that dry bogs (without winter flowage) near the station bog showed but little of the tip injury in 1911. The station bog was resanded in the fall of 1911, and the winter flowage was held late (until the 17th of May) the following spring. In 1912, little of the injury occurred on the bog, the bud formation for the following season being almost perfect and resulting in the splendid crop obtained in 1913. In 1913, the injury was again considerable, though the bud development was fairly good, and the 1914 crop

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[1] Entomological News, XXVI, 1915. (*Campoplex variabilis* n. sp.).

following those conditions was a fair one. This year the tips died badly, and the budding for 1915 was poor.

The tips have been carefully examined every year since this trouble was first noticed, but the cause of the injury was not discovered with certainty until 1914. The tip worm was suspected from the first, but as the maggots of the broods which appear before blooming time were known to always make their cocoons in the tips of the vines, the cocoons remaining as certain evidence of their work even after the flies themselves had emerged and disappeared, it was thought that at least cocoons, if not maggots, ought to be found in connection with the tip injury coming after the bloom, if it was caused by this insect.

This year a special effort was made to ascertain the cause of the trouble. The tips were examined before they showed injury, while the bog was in full bloom, and maggots in various stages of development were soon found in a good share of them, as many as five sometimes being present in one tip. Tip worm eggs were also found in abundance. In less than three weeks the infested tips had dried up, the maggots having disappeared without leaving cocoons. There was no longer any doubt as to the cause of the injury observed in previous seasons. It was soon found that the maggots of this, the most injurious brood, leave the tips and go down to the sand under the vines to form their cocoons. Unfortunately, it was not discovered in what condition the insect passes the winter. It is suspected that it may remain in the cocoon and be able to endure winter flooding.

As soon as this insect was found in such abundance on the station bog an examination of other bogs was begun, and a great variation was found among them in the amount of tip worm damage, due, apparently, to the treatment they had received. Two-thirds of the tips on the station bog were injured, and practically all of them were hurt on a bog of 4 or 5 acres in Carver. On some bogs, however, the damage was only from 3 to 5 per cent. From 50 to 60 bogs were examined in the course of this investigation, and it resulted in the following conclusions: —

1. That flowed bogs, in case they had not been resanded before the 1st of May, were, as a rule, much more seriously injured than were strictly dry bogs (without winter flowage). In its relative abundance on dry and flowed bogs, the tip worm seems to be in a condition similar to that of the flowed-bog fireworm, though the reasons for the condition may not be the same with both species.

2. That flowed bogs which had been resanded the fall before or in the spring before the 1st of May were, as a rule, much less seriously injured than those not thus resanded. In nearly every case those most hurt had not been resanded for two years or more.

3. The "Late Howe" variety, as a rule, showed distinctly more injury than did the "Early Black."

4. No bog showed great tip worm injury where traces of severe frost damage were in evidence.

5. This seems to have been a year of exceptional tip worm abundance. It is not yet certain why resanding, winter flooding, difference in variety and frost have bearings on the prevalence of this insect. It seems evident, however, that resanding every other year should be recommended as a wise preventive practice against it.

The injury caused by this brood which does its work during the time of full bloom is a matter of great importance. It has undoubtedly been the cause of many a crop failure supposed to have been due to other troubles. Early in October, the tips on the station bog were carefully examined to find out whether there had been much recovery from this injury. It was found that less than half of the injured tips had formed buds for next season. The following count of "Late Howe" tips, made on October 1, showed the most recovery of all the counts made: tips not injured, 39; injured tips which had recovered and formed buds, 31; injured tips which had not formed buds, 34. In many cases the buds on the recovered tips were undersized, and it seemed doubtful if the majority of them were normal. The poor recovery on the station bog may, of course, have been due to a devitalized condition of the vines, but the evidence at hand indicates that this insect is a very serious pest.

The Flowed-bog Fireworm (*Rhopobota vacciniana* (Pack.)).

General observations concerning this insect were made during the year, but no extensive experiments were carried out with it because the tip worm and fruit worm monopolized attention. It seems wise, however, to sum up in this report the possibilities for treating this insect satisfactorily.

1. Where reflowing can be done in June, reasonably effective treatment may be had by using the water according to suggestions and recommendations made in previous reports, and perhaps no improvement in treatment is possible for such bogs.

2. Winter-flowed bogs which cannot be reflowed must either have the flowage held late enough (until, perhaps, June 20) to kill the eggs, as often as an infestation develops sufficiently to do serious damage, the crop being sacrificed in the years of such late holding, or else be sprayed, if any direct treatment is to be applied at all. Arsenical poisons seem to have been pretty thoroughly tested by the growers in practical spraying for this insect. A great advantage is often obtained by their use, but under some conditions the results are very unsatisfactory, and the frequent failures with such treatments have created a general desire for some better method. Only one possibility for great improvement in spraying treatments seems to present itself. Possibly a sweetened spray would be attractive to the worms. Some growers claim to have tried such a spray with exceptionally good results, but it is doubtful if this method of treatment will be found practicable on more extensive trial. Sweetened sprays are nowhere widely used in treating any chewing insect, and if such a treatment were practicable it would probably have come

into extensive use with other insects long ago. Sweetened poison baits have long been widely used against grasshoppers and cutworms, and molasses is commonly used by entomologists to attract many kinds of moths in night collecting. Sweets are, therefore, evidently liked by many insects, and the idea of sweetening arsenical sprays seems worth trying out thoroughly on that account. The fireworm's hatching period, however, often covers several weeks, and, in order to be satisfactorily effective, any poison application must remain on the vines in considerable strength for quite a long time. Sweets being very soluble in water, if used in a spray, will not remain on the vines long if much rain falls. There are, therefore, considerable difficulties to be overcome in making satisfactory use of a sweetened spray.

The outlook, therefore, does not seem bright for treating this insect more satisfactorily by direct methods. It may be possible, however, to treat it indirectly in some way. As stated in previous reports, it does not seriously infest bogs without winter flowage. If infested bogs could be left entirely without flowage, the insect would in time probably be controlled by weather conditions and its natural enemies. If bogs are not winter flowed, however, other troubles have to be met. In the first place, there is the danger of winterkilling, though this factor is not as important as is generally supposed, for severe winter injury does not occur on dry bogs oftener than once in four or five years, and even then the bogs are seldom so hurt that they do not produce partial crops and recover in fair shape for the following year. The fruit worm increase which takes place when winter flowage is omitted is, however, a serious matter, and a satisfactory treatment for that insect is, for that reason, a possible key to the fireworm situation. If the fruit worm could be controlled without winter flooding, the forces of nature could be brought to bear in the fight with the fireworm by omitting flowage altogether.

The Cranberry Fruit Worm (*Mineola vaccinii* (Riley)).

Late holding of the winter flowage continues to be the only certainly reliable method of dealing at all satisfactorily with this insect. A better treatment is desired because the water does injury when held late every year. Any new treatment of value must probably be an indirect one.

As stated in last year's report (page 57), tests showed that the cocoons of the fruit worm are not impervious to water, for they were found to be wet inside when carefully opened after only a few minutes' submergence, the water apparently having penetrated them almost instantly. This was further tested later by wetting dry cocoons with a spray from a Vermorel nozzle, and the water seemed to strike through them as readily as it would have through a handkerchief. It seemed from this that it might be possible to kill the worms in their cocoons on the bog by spraying with some contact poison, as the spray would evidently soak through the cocoons at once. The writer conducted laboratory experiments with "Scalecide" and "Black Leaf 40" to determine what strength of each it would take to kill the worms in this way. They were not killed when the cocoons were kept wet with a mixture of 1 part of "Scalecide" in 5 parts of water for a whole hour. As it would take not less than 600 or 700 gallons to wet down the surface of the sand on a bog, especially if the vines were at all thick, it became evident without further tests that "Scalecide" could not be used successfully in this way because of expense. It took a strength of 1 gallon of "Black Leaf 40" in 100 gallons of water to kill the worms when sprayed on the cocoons, and therefore treatment with this insecticide also seems too expensive to be practicable. However, further tests with other contact sprays are planned.

For dry bogs (without winter flowage) the possibilty of starving out this insect by destroying the bloom in seasons of light crop promise is still under consideration. Success in killing the blossom by spraying with a 20 per cent. solution of iron sulfate was reported last year. As it took three sprayings to destroy all the blossoms, however, it appeared that there might be danger in this method of treatment, as the application of so much iron sulfate might injure the vines. To determine this point, the sulfate salt was applied broadcast on two bog plots on June 17, this year, at the rate of 1 ton to the acre. A few of the vines showed a little injury afterward, but as far as the evidence obtained went, the sulfate may be used to kill the bloom without fear of its doing much damage. It is planned to test this matter further, however.

The study of the natural enemies of the fruit worm were continued, and many things of scientific importance were learned about its parasites. Some of this new information may in time lead to valuable practical results. In all, nearly a dozen species parasitic on this pest have been bred, but only three of them are abundant enough to be of much importance. These three species are: —

1. A Braconid (*Phanerotoma tibialis* Hald.), discussed in last year's report (pages 55 and 56). Cocoons containing worms parasitized by this species can usually be readily distinguished from those of normal, unparasitized worms by their much smaller size. When this parasite was reported on last year, it was assumed that it laid eggs in the eggs of the fruit worm when it parasitized them. This year's observations, however, seem to indicate that instead of laying eggs it injects living young into the fruit worm eggs, and is therefore viviparous. The writer failed to find the eggs of the parasite, but its larvæ can readily be found in fruit worm eggs even before the worms themselves have taken distinct form.

2. An Ichneumonid (*Pristomeridia agilis* (Cress.) Ashm., determined by R. A. Cushman of the United States national museum). This species was also mentioned in last year's report (page 56), but more knowledge concerning it has been obtained this year. It inserts its elongate, curved, black eggs into the body of the fruit worm, usually accomplishing this by sticking its egg-laying apparatus into the hole made in the berry by the worm. The eggs hatch within a few days after they are deposited in the tissues of the worm. This is a far less important parasite than the Braconid

(*Phanerotoma*), not only because it is much less abundant, but also because it usually deposits its eggs in worms which have already been parasitized by the Braconid. It is perhaps as much of a hindrance as a help because of this interference with the Braconid.

3. A Chalcidid (*Trichogramma minuta* Riley,[1] which is known to be parasitic on the eggs of forty-six other species of insects, the codling moth, the brown-tail moth, the pear-slug, the elm saw fly (American Cimbex), the fall web-worm, the corn ear-worm and the cotton worm being some of its important hosts). This, the most important parasite of the fruit worm, was a new find this year. It undergoes all its development and transformation in the fruit worm egg, causing the destruction of the egg, as far as the development of the worm is concerned, and emerging from it in July and August as a full-grown fly-like creature of such small size as to be hardly visible to the naked eye. Its presence in the eggs may be readily detected by their appearance, for they turn black when infested with it. Moreover, when the fruit worm itself hatches, the eggshell is left looking like a white flake, and the worm's place of emergence is not readily seen because of its location close to the surface of the berry. On the other hand, when the parasite has emerged the eggshell looks black and the emergence hole is conspicuous. The writer has noticed these black eggs several seasons, and, as he suspected parasitism in connection with them, he attempted to rear the parasites last year, but failed to do so, probably because the methods he employed were not suited to these very delicate creatures. This year, however, different methods were tried, and the adult parasites were obtained in considerable numbers without much trouble. This parasite destroyed about 56 per cent. of the fruit worm eggs on dry bogs near the station bog this year, about 700 eggs having been examined in making this estimate.

In last year's report (page 55), it was estimated that more than 50 per cent. of the fruit worms on a dry bog near the station bog had been parasitized in 1912. As nothing definite was then known about the Chalcidid egg parasite and its importance, that estimate was much too low, this year's investigations having shown that the natural enemies (parasitic and predacious) of the fruit worm took care of not less than 90 per cent. of the infestation on dry bogs, and of fully 66 per cent. on flowed ones, in the vicinity of the station during the season.

The writer's findings concerning the natural enemies of the flowed-bog fireworm and the bearing which flooding has on their effective activity have been discussed fully in previous reports, but they must be briefly brought to mind again here to show how they are supported by the results of this year's study of the distribution of the principal fruit worm parasites. The fireworm seriously damages only flowed bogs, and it becomes a pest because the flowage either drives out or destroys its natural enemies,

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[1] Since this was written, this determination has been confirmed by Mr. A. A. Girault, the authority on the *Trichogrammatidæ*.

but does the insect itself no similar harm. A fireworm infestation always becomes noticeably injurious first at some distance from the upland, and bogs of large size and compact form are much more often badly infested than are smaller ones. This is due to the fact that it takes some time for the natural enemies of the pest to work in from the upland and become effectively numerous on all parts of a large bog, especially on the middle part, after the spring flooding is done. In connection with this fireworm situation, the following findings, concerning this year's distribution of fruit worm parasites on the station bog and on a dry bog near by, are distinctly interesting, the figures given in the table showing the percentage of fruit worm eggs or worms found parasitized in the different locations indicated: —

TABLE 6. — *Distribution of Effectiveness of Principal Fruit Worm Parasites.*

PARASITE.	Eggs or Worms of Fruit Worm examined.	Dry Bog.	Center of Station Bog.	Edge of Station Bog. (1)	Edge of Station Bog. (2)	Edge of Station Bog. (3)
Chalcidid, . .	Eggs, . .	56.0	14.0	28.0	44	–
Ichneumonid, . .	Worms, . .	26.4	4.6	10.4	10	10.6
Braconid, . . .	Worms, . .	47[1]	43[1]	–	–	–

[1] Because of a mathematical error by the writer, the percentages (32 and 30) given in the Report of the 27th Annual Meeting of the Cape Cod Cranberry Growers' Association, 1914, page 21, were incorrect.

It will be seen that the distribution of the Chalcidid and Ichneumonid parasitism was, in a general way, like that found to obtain, as shown in previous reports, with the enemies of the fireworm. The dry bog used in this comparison is about two acres in area. The center of the station bog is about 250 feet from the upland. The three "edge of station bog" locations were on different sides of the bog. The examinations on which these figures are based were made during the first two weeks in August. Each figure is an average, representing numerous examinations. The station bog was reflowed for the last time a little over seven weeks before these parasite investigations were made. When all these facts are considered, the great influence of flooding on the distribution of the first two of these parasites becomes at once apparent. It will be seen, however, that the water did not seem to affect the Braconid very much, the results of the investigation in this regard being contrary to those of last year's rearing tests. If last year's report is referred to (page 56), however, the following remark concerning the results of those tests will be found: "From a study of the life history of *Phanerotoma tibialis*, it is not easy to see just how the flowage can affect its prevalence to so marked an extent." In the present opinion of the writer it will be found that flooding does affect the abundance of *Phanerotoma* considerably, though probably not to the extent indicated by the results of the 1913 investigations.

In studying the fruit worm parasitism, the writer has had the two following practical objects in view: —

1. *The Possibility of forecasting Seasons of Great Fruit Worm Injury.* — If relative abundance and scarcity of the parasites in different years has a strong bearing on the comparative abundance of the pest, we should probably be able to foretell with some degree of accuracy, after keeping records of the parasitism for several years, what is to be expected in this regard several months ahead.

2. *The Possibility of increasing the Natural Effectiveness of the Parasites by harboring them artificially in Some Way.* — Not enough has yet been learned about the Chalcidid parasite to make any definite plans in relation to it in this connection. The Braconid (*Phanerotoma*), however, can probably be handled without much difficulty, and experiments are already under way to determine whether its percentage of mortality is much greater under natural out-of-door "dry bog" conditions than it would be if its host worms were kept under the more even conditions of temperature and moisture which they would have in cold storage or in ordinary cellars. It is evident, of course, that on flowed bogs the majority of these Braconid parasites perish during the winter, and if the water is held late (until the latter part of May) they are probably almost exterminated. If, therefore, they can be wintered under artificial conditions without much loss, it ought to be possible to replenish the *Phanerotoma* parasitism on flowed bogs by gathering fruit worms every summer, allowing them to form their cocoons in captivity, wintering them in cold storage and returning the parasites to the bog when they emerge the following season. Of course many unparasitized worms would be wintered in this process, and as a result many moths would emerge with the parasites, but there is so much difference in size between the moths and parasites that they could be readily separated with a screen. After they were separated the moths, of course, would be destroyed.

Further submergence tests with fruit worms in their cocoons were begun on September 7, 15 different lots of a dozen each being submerged in water in long glass tubes 2 inches in diameter, at depths varying from 4 to 67 inches, on that date. All the worms used in these tests were collected from a bog, in their berries, between the 12th and 21st of August. They were submerged seventeen days, being removed from the water on September 24, and were all found to have been killed by the treatment. The tubes were kept in the station screen-house during these tests, and the water may have killed the worms because of its abnormal stagnation and high day temperature.

On October 19, further submergence tests were started, a part of the cocoons being put in water in tubes in the screen-house as before, while a part were submerged in light netting sacks suspended from a float in a pond. Some of these cocoons were removed from the water on November 4, after sixteen days of submergence, while others were kept submerged for twenty-five days, until November 13. On both dates it was found that all the worms which had been in the glass tubes were dead, while most of those taken from the pond were alive and capable of crawling actively soon after they were taken from their cocoons. The results of this test led to the suspicion that the worms in the tubes had died because of the extreme stagnation of the water, while those in the pond had perhaps been kept alive by air thrashed into the water by the wind.

A third lot of tests was started on November 12, two of the long glass tubes used in the previous tests being submerged in an upright position in a pond, netting sacks containing fruit worms in their cocoons being tied inside the tubes and also outside of them at different depths ranging from 9 to 61 inches. One tube was taken from the water on December 15 and the other on December 22. Of the 23 worms submerged with the former tube, the 6 outside ones were all lively, while 8 of the 17 inside were dead. Of the 21 worms submerged until the 22d, the 5 outside were all very much alive, while 3 of the 16 inside were dead. The tubes got dragged badly by the ice just before the first one was taken from the water, and most of the cocoon-containing sacks attached to the outside were torn from both, one being left with each. On the whole, the worms endured this prolonged submergence remarkably well. The stagnation of the water inside the tubes seemed to harm them somewhat.

From these and other submergence tests, it was learned that the fruit worm in its cocoon has great ability to resist drowning aside from any protection provided by the cocoon. The cocoons completely filled with water in about five days, so that the worms within them were entirely surrounded by it, there being no air bubble left to help keep them alive.

Water Movement in Peat.

As a part of the general study of cranberry bog drainage and irrigation, it seemed desirable to learn something about the rate of the passage of water through peat, as compared with its movement in other soils. For this purpose, on May 25, 12 holes 3 feet deep were dug 8 feet apart in the station bog, in a line running straight across a section 96 feet wide, those at each end of the line being located 4 feet from the ditch. Stakes were driven in these holes, and levels from which to measure the rise and fall of the water in each were carefully determined and marked upon them. In the latter part of May and in June and July observations and records were made, in connection with the vertical movement of the water in these holes, whenever the bog was being flooded or drained.

The record of May 29 is given here in full, it being fairly representative. In the morning, the ditches surrounding the section in which the holes were dug were comparatively empty, no standing water being visible in any except the large main ditch. The water level in one of the two middle holes (hole No. 7) was taken just before the bog pump was started at 9.30 A.M. and was found to be 97.16, as measured from a bench mark the elevation of which was regarded as 100 feet. It was practically the same in hole No. 6. The pump was run for one and one-quarter hours, until 10.45 A.M., when holes Nos. 1 and 2 on one side of the section and Nos. 11 and 12 on the other side were full of water which had run over the surface of the sand into them. The water level in the ditches and these holes was then, as measured from the bench mark, 98.75. The surface water had not run into the other holes at all or come anywhere near them. At noon, one and one-quarter hours after the pumping was done, the water levels in the 12 holes and in the ditches were taken and found to be as follows: —

Ditch,	98.48	Hole No. 7,	98.07
Hole No. 1,	98.53	Hole No. 8,	98.10
Hole No. 2,	98.34	Hole No. 9,	98.17
Hole No. 3,	98.17	Hole No. 10,	98.09
Hole No. 4,	98.15	Hole No. 11,	98.30
Hole No. 5,	98.09	Hole No. 12,	98.37
Hole No. 6,	98.00		

This record shows a variation of only about 6⅓ inches in the water level two and one-half hours after the pumping was begun. Similar measurements were made again at 3.30 P.M., six hours after beginning pumping and four and three-quarters hours after stopping, and the variation was then found to be only about 1⅔ inches, the various levels being as follows: —

Ditch,	98.29	Hole No. 7,	98.21
Hole No. 1,	98.29	Hole No. 8,	98.21
Hole No. 2,	98.26	Hole No. 9,	98.26
Hole No. 3,	98.20	Hole No. 10,	98.21
Hole No. 4,	98.20	Hole No. 11,	98.26
Hole No. 5,	98.17	Hole No. 12,	98.26
Hole No. 6,	98.15		

The pump was started again at 4.20 P.M. (May 29) and run until 7 P.M. The planks were then put in, and all the water was held until 2 A.M. the following morning, at which time the water level on the bog was 99, all the 12 holes used in making the above measurements being entirely full. The water was allowed to run out of the bog freely from 2 A.M. until 10.45 A.M., when the levels in the ditches and in the holes were again taken and found to be as follows: —

Ditches,	97.48	Hole No. 7,	97.78
Hole No. 1,	97.57	Hole No. 8,	97.71
Hole No. 2,	97.71	Hole No. 9,	97.72
Hole No. 3,	97.71	Hole No. 10,	97.76
Hole No. 4,	97.73	Hole No. 11,	97.66
Hole No. 5,	97.71	Hole No. 12,	97.63
Hole No. 6,	97.79		

The elevation of the surface of the peat around these holes averaged roughly about 98.59. There was, therefore, a drainage in the peat of considerably over 9 inches in less than nine hours, at the middle of the section, at a distance of 44 feet from the nearest ditch. This shows that the horizontal movement of water through the peat of cranberry bogs is a very rapid one, if conditions at the station bog are representative.

Root Development.

A study of the seasonal development of the root growth of the cranberry was begun in a rough way and produced some interesting results. As stated in last year's report, Professor Coville, of the Bureau of Plant Industry of the United States Department of Agriculture, has found that the root development of blueberries, rather closely related to the cranberry, is very sluggish. This is also found to be true of the cranberry, though apparently not to so great an extent. On the fungous plots of the station bog this year there was practically no new root development until after the vines had bloomed, and most of the new growth came after blossoming time on the bog as a whole. The new roots were found, however, to start fairly early on bogs which are not winter flowed, some new growth being discovered on well-sanded portions of such bogs as early as May 7.

The winter flowage was let off from the station bog on May 5, and no new roots could be found on it on May 7. On May 26, a considerable growth of new rootlets had already taken place near the surface, but the lower roots showed no new development whatever. A season's root growth on cranberry bogs evidently begins, therefore, at the surface of the sand, where the roots have the most air and heat. In examinations made later in the season new roots were finally found deeper down in the bog, but the conditions that favored the starting of development near the surface evidently continued to have their influence more or less throughout the period of growth, causing the greater part of the season's root growth to be developed within two or three inches of the surface.

The degree of drainage does not seem to affect the new root development in the first part of the season (before the 1st of June), except that when the water table is so high (within three or four inches of the surface) that it makes the surface sand soppy the new rootlets are distinctly larger and more succulent than when they grow under dryer conditions.

Studies of the *Mycorhiza* fungi on cranberry roots were begun in a rough way, with the idea of first finding out, if possible, whether there is any great difference in the abundance of these fungi present in different sorts of bogs, attention being given particularly to comparisons between flowed and dry bogs, old bogs and new plantings, and vines growing on "hard bottom" and on "peat bottom." While this investigation has not advanced far enough to justify definite conclusions, it is apparent that different bog conditions have a considerable bearing on the abundance of these fungi.

Miscellaneous.

After most of the cranberry crop had been gathered, the fallen berries were picked up from under the vines on a large number of measured plots on the station bog and other bogs in the vicinity, to determine how much of the fruit was lost in different methods of harvesting. The loss ranged from an average of about 10 per cent. where the scoops were handled slowly and carefully to an extreme loss of over 25 per cent. where bogs with heavy crops were scooped hurriedly. The general conclusion arrived at from this investigation was that with low prices such as obtained this year, especially with the early berries, it is advisable to scoop rapidly on bogs with light or medium crops. Under the normal price conditions of previous years, however, it would pay, with heavy or medium crops, to pick slowly and carefully, prevention of waste being much more important than the keeping down of the labor expense of picking. It would sometimes pay, under such conditions, to spend as much as 80 cents a barrel on "Early Blacks" and $1 a barrel on "Late Howes" for careful scooping. Most of the berries dropped in scooping seem to be knocked off by the tips of the teeth of the scoop. For this reason, a scoop with teeth having rounded and flattened ends would probably lose less berries than one with pointed teeth.

This year of low prices has been generally discouraging to the cranberry growers. It will undoubtedly, however, benefit those interested in the industry to some extent by tending to curtail the planting of new bogs in the immediate future. Such prices may not prevail again for many years, for, as is generally realized, this year's conditions were very exceptional in many ways. If the time ever comes when very low prices are the rule year after year, the situation will not be hopeless, for, as in every other business, changes in methods will necessarily accompany changes in conditions. With low prices the rule, no attempt probably would be made by most growers to combat the various pests by methods now employed. The fruit worm, flowed-bog fireworm, tip worm and various other insects which occasionally become troublesome would be entirely controlled by holding the winter flowage very late (perhaps until nearly the 1st of July) every other year (or possibly every third year). Though the crop would be entirely lost in the year of late holding, its loss would be largely offset by the almost entire elimination of expense, and the crop of the following year, being free from the most commonly troublesome pests, and having behind it the strength of vines not weakened by the drain of a crop the year before, would give the best returns possible. The average quantity of berries produced yearly would perhaps not be as great as that obtained by present methods, but even with low prices the profits might not be seriously diminished, since a considerable reduction in expenses would be brought about by such management.

Cranberry growers frequently desire to know how high a temperature the water of June reflowage can have without doing serious damage to the buds. The experience at the station bog in the last two seasons, therefore, should be both interesting and reassuring. Very hot weather occurred both years during the regular June reflow. The temperature of the water on the bog was taken with a Green thermometer, and the maximum reading obtained each year was 86° Fahr. In 1914, the reflow was continued for two days, the temperature of the water being 86° Fahr., at noon the first day and 81° the second. The withdrawal of the flowage was started at 2 A.M., the temperature of the water at that time being 71°. Higher temperatures probably will seldom be experienced in flooding. There was practically no damage to the buds.

Blueberries.

Owners of many "dry bogs" on the Cape will be interested to know of the work which has been done with blueberries in the New Jersey cranberry growing region. Prof. Frederick V. Coville of the United States Department of Agriculture and Miss Elizabeth C. White of New Lisbon, N. J., have co-operated in the selection and breeding of blueberries and have produced varieties with fruit of such superior size that the commercial growing of this fruit is soon to be taken up extensively by some of the New Jersey cranberry growers. There seems to be no reason why these blueberries should not do as well on Cape Cod as in New Jersey, and the peat soils used for growing cranberries are entirely suitable for them. Many dry bogs which are at present poor investments could, without doubt, be converted into blueberry plantations with great profit.

DEPARTMENT OF PLANT AND ANIMAL CHEMISTRY.

J. B. Lindsey, *Chemist in Charge.*

THE EFFECT ON A CROP OF CLOVER OF LIMING THE SOIL.

BY F. W. MORSE.

This study of the effect of liming a soil on the composition of a crop of red clover has been made in the course of investigating soil-fertility problems connected with the oldest series of fertilizer plots at the Massachusetts Agricultural Experiment Station. The plots have been repeatedly described in the annual reports of the station, under experiments with nitrogenous fertilizers, and designated as "field A."

A brief description of the plots at this point will serve to make this particular study intelligible. The soil is a sandy loam, and the plots referred to in this paper have received only chemical fertilizers for a period of thirty-one years. No dung or litter has been applied, and organic matter has been supplied wholly by crops grown on the land in the form of roots and stubble, with an occasional catch crop plowed under.

Since 1890 the annual application of chemicals has been 45 pounds of nitrogen per acre in nitrate of soda or sulfate of ammonia; 80 pounds of phosphoric acid per acre in dissolved bone black, and 125 pounds of potash per acre in muriate of potash or the double sulfate of potash and magnesia.

Table I. shows the distribution of the different fertilizers among the plots.

Table I.

Plot 1. Nitrate of soda, dissolved bone black, muriate of potash.
Plot 2. Nitrate of soda, dissolved bone black, sulfates of potash-magnesia.
Plot 4. No nitrogen, dissolved bone black, sulfates of potash-magnesia.
Plot 5. Sulfate of ammonia, dissolved bone black, sulfates of potash-magnesia.
Plot 6. Sulfate of ammonia, dissolved bone black, muriate of potash.
Plot 7. No nitrogen, dissolved bone black, muriate of potash.
Plot 8. Sulfate of ammonia, dissolved bone black, muriate of potash.

The more recent history of cropping is as follows: in August, 1906, alsike clover was sown in the standing corn then occupying the field. The land remained unplowed for three years. The stand of clover was poor, and each spring additional seed was sown on the surface, but grasses crowded into the bare spaces. In August, 1909, one-half of the field was limed at the rate of 3,000 pounds per acre with slaked lime, the application being made crosswise of the plots, so that every plot was half limed and half unlimed. Alsike clover was again sown, but as in preceding years the crop of 1910 consisted of more grass than clover.

In 1911 and 1912 corn was grown with good yields on all plots, and in the former year the product of the plots receiving no nitrogen, plot 4 and plot 7, was practically equal to that from plots 1 and 2, which received nitrate of soda. Attempts to get a stand of alsike clover were made in both years by sowing the seed in the standing corn late in July. Germination was good, but the clover was badly winterkilled both years.

The liming of one-half of the area in 1909 showed no appreciable results on either corn or clover. Therefore in 1913, when it was apparent that the land must again be plowed, another dressing of hydrated lime was applied at the rate of 4,000 pounds per acre.

Japanese millet was grown in 1913 with fair yields, but the crop was cut short by drought. The growth did not appear to be much influenced by the lime. In the spring of 1914 the plots were seeded with red clover, together with oats as a nurse crop. The oats were removed in July, and there were pronounced effects of the liming observable on all the plots, least on the plots receiving nitrate of soda.

After the oats were removed the clover on the limed halves of plots 4 and 7, receiving no nitrogen, was first to appear above the stubble. The clover on the whole area of plots 1 and 2, receiving nitrate of soda, and on the limed halves of plots 5, 6 and 8, receiving sulfate of ammonia, followed about one week later.

As the season progressed the clover on the limed areas receiving no nitrogen continued to lead all the other plots in size and vigor of growth, and began to bloom several days ahead of them. The whole area receiving nitrate of soda looked uniform to the eye, but a little behind the limed area without any nitrogen. The limed areas receiving sulfate of ammonia were like the areas receiving nitrate of soda. The unlimed areas without nitrogen produced a slow-growing crop which looked scanty in comparison with the growth on the limed portions of the same plots, but an examination of the ground showed the plants to be as numerous on one area as on the other. The clover on the unlimed areas receiving sulfate of ammonia looked noticeably inferior to all other plots without lime, and the division between the limed and unlimed halves of the plots was clearly marked by vigorous, thrifty plants on the limed areas and small stunted ones on the unlimed. A similar line of demarkation existed on the plots receiving no nitrogen, but was barely, if at all, noticeable on the plots receiving nitrate of soda.

The pronounced effect of liming the soil on the growth of clover made it seem possible that a chemical investigation would show some specific effect of the lime on the composition of the plants. Accordingly, samples of clover plants were gathered from both limed and unlimed areas of the plots mentioned in Table I. and samples of clover roots from both halves of plots 2, 5 and 7.

The samples of clover were obtained on Sept. 14 and 15, 1914, when the crops on the limed halves of plots 4 and 7, without nitrogen, were in full bloom, and on the other limed areas were partly so. The unlimed halves of plots 1 and 2, dressed with nitrate of soda, appeared to be as much in bloom as the limed halves, but the remaining unlimed areas showed no flowers nor buds. The samples were gathered by cutting the plants near the ground with grass shears, and each half of a plot was represented by a large number of plants which were taken from all sections of it. The unlimed areas of plots 4, 5, 6, 7 and 8 were most thoroughly represented because the growth on them was so much smaller that many more plants were needed to make samples of sufficient size.

The samples of clover roots were obtained by digging representative plants with a spade, taking up a block of soil about 8 inches in depth. The blocks of soil were exposed to the action of water from a hose-nozzle, care being taken that the rootlets were not broken as the soil was washed away. The process was slow, and it required the time from September 16 to 19, inclusive, to prepare the samples desired. The samples were, however, obtained under uniform conditions, as the weather was fair throughout the sampling. After the roots were washed free of earth they were cut from the plants and dried.

The roots from both halves of plot 2, dressed with nitrate of soda, were large and thrifty and bore numerous nodules. The roots from the limed halves of plots 5 and 7 were apparently similar in all respects to those from plot 2. On the other hand, the roots from the unlimed half of plot 5, dressed with sulfate of ammonia, were much smaller than those from the limed half, and nodules were few and very small. The roots from the unlimed half of plot 7, receiving no nitrogen, were thriftier than those just described, but were not so thrifty in appearance as those on the limed half and bore smaller nodules.

All samples were dried at a temperature around 75° C. until sufficiently brittle to be easily pulverized. They were then ground to a powder, after which moisture was determined in order that all subsequent analytical work could be based on the dry matter. No attempt was made to determine the percentage of dry matter as it was not essential.

The tentative plan for chemical analysis included total nitrogen as the most easily determined organic constituent, total ash as a guide to the mineral constituents, iron oxide and calcium oxide. Iron oxide seemed important because in our soil-fertility investigations Mr. Ruprecht has found soluble iron salts in the unlimed areas of some of the plots,[1] and has studied their effects on the growth of clover.[2] The percentage of calcium oxide in the clover was expected to be modified by the application

[1] Investigations not yet published.

[2] See second part of this bulletin.

of lime to the soil, and it was also thought that the iron oxide would be modified somewhat by it. The results of the analytical work are given in Table II.

Table II. — *Composition of Clover (Dry Matter) (Per Cent.).*

		Plot 1.	Plot 2.	Plot 4.	Plot 5.	Plot 6.	Plot 7.	Plot 8.
Ash,	Limed,	11.04	10.79	10.39	10.64	10.35	10.85	10.92
	Unlimed,	10.99	10.31	10.82	10.68	10.51	11.16	11.40
Ferric oxide,	Limed,	.11	.14	.06	.15	.11	.12	.09
	Unlimed,	.13	.13	.09	.20	.09	.16	.12
Calcium oxide,	Limed,	2.04	1.80	1.63	1.85	1.99	1.90	2.01
	Unlimed,	2.21	1.96	1.95	2.05	2.46	2.43	2.51
Nitrogen,	Limed,	3.71	3.60	3.53	3.57	3.66	3.39	3.73
	Unlimed,	3.49	3.28	3.06	2.74	2.64	2.80	2.88

Composition of Clover Roots (Dry Matter) (Per Cent.).

		Plot 2.	Plot 5.	Plot 7.
Ash,	Limed,	7.25	6.79	6.26
	Unlimed,	7.31	7.93	7.12
Ferric oxide,	Limed,	.40	.40	.24
	Unlimed,	.47	.61	.36
Calcium oxide,	Limed,	.59	.53	.60
	Unlimed,	.48	.41	.54
Nitrogen,	Limed,	2.77	2.77	2.45
	Unlimed,	2.43	1.76	1.88

The composition of the samples of clover from the limed areas proved to be more uniform than the composition of samples from the unlimed, the range of percentages between maxima and minima being narrower in the constituents of the former series. The mineral constituents are slightly higher in the clover from the unlimed areas, and this is most positively defined in the percentages of calcium oxide. On the other hand, the nitrogen is markedly lower in the unlimed group of samples.

The composition of the roots differed somewhat from that of the tops. The constituents determined, except iron oxide, were much lower in percentage than those in the tops. The percentages of nitrogen varied in the same manner as in the tops, while calcium oxide was higher in the roots from limed areas, and the iron oxide was higher in those from unlimed areas.

Variations in the percentages of ash in the roots were probably due in part to the presence of clay, which could not be completely washed from the roots. This was clearly indicated by the following experiment. Parallel ash determinations were made on the roots from the unlimed half of plot 5 and those from the limed half of plot 7, which represented, respectively, the maximum and minimum ash percentages. After weighing the total ash it was dissolved in strong hydrochloric acid, then diluted with water and filtered. The insoluble residue on the filter was then ignited and weighed. The soluble ash percentages were nearly alike.

	Plot 5, Unlimed (Per Cent.).	Plot 7, Limed (Per Cent.).
Total ash,	7.45	6.24
Insoluble residue,	2.24	1.20
Soluble ash,	5.21	5.04

The percentages of ash, iron oxide and calcium oxide throw no light on the specific effect of liming the soil. There appears to be neither too much iron nor too little calcium in the tissues of the plants from the unlimed areas, unless the small differences in the percentages from limed and unlimed roots are sufficient to warrant such a deduction.

The marked differences in the nitrogen percentages in the unlimed crops when compared with those in the limed crops justify the deduction that available nitrogen was an important factor in promoting the growth of the plants. It is well known that carbonate of lime is beneficial to bacterial development; therefore it is reasonable to conclude that fixation and nitrification of nitrogen have been accelerated on the limed areas to the marked advantage of the plants, in comparison with those on the unlimed areas.

The increased formation of available nitrogen can be considered as true even for the plots receiving nitrate of soda, because 45 pounds of nitrogen would be completely used in 1,233 pounds of dry matter containing an average of 3.65 per cent. of nitrogen, which is the average for the crops from the limed halves of plots 1 and 2. That amount of dry matter represents a small yield of clover hay per acre, to say nothing of the roots of the crop, which contained 2.77 per cent. of nitrogen. In this instance the clover was not harvested, and we have no weights to confirm our opinion.

Besides the lessened availability of the nitrogen on the unlimed halves of the plots dressed with sulfate of ammonia there was also the probable hindrance to root development due to the presence of sulfate of iron and sulfate of aluminum, noted by Mr. Ruprecht in his work on the soils from these plots. As already noted in the description of samples, the roots obtained from the unlimed half of plot 5 were much smaller than those from the limed half, although they did not show the thickened, dwarfed forms obtained in some of the water cultures.

The results of this work point to an effect of the lime on the soil constituents, by which the root environment is improved, rather than to an effect within the plant by the absorption of a larger amount of calcium salts.

TOXIC EFFECT OF IRON AND ALUMINUM SALTS ON CLOVER SEEDLINGS.

BY R. W. RUPRECHT.

During the study of the soil from field A it was found that marked amounts of soluble aluminum and iron salts were removed from the plots receiving sulfate of ammonia by long-continued washing of the soils with distilled water, while no aluminum and only traces of iron were removed from the plots receiving nitrate of soda. This led to the conclusion that the iron and aluminum salts might be the causes of the poor crops, and water-culture work, using these salts, was undertaken.

At the time these culture experiments were started practically no work of this nature, using iron and aluminum salts in water cultures, had been reported. Since then, however, Connors of Indiana has published[1] results of the toxic action of aluminum on corn seedlings, and Gile has published[2] results of the toxic effect of salts of iron on rice seedlings.

The salts used by me were ferrous sulfate and aluminum ammonium sulfate. The alum was used instead of aluminum sulfate because the latter was not on hand.

Standard solutions of the above salts of one-tenth molecular strength were made up, and different amounts were added to the nutrient solution.

The nutrient solution used was a slight modification of Pfeffers, and was made up as follows: —

Solution (*a*): 20.5 grams $MgSO_4$ dissolved in 350 c.c. distilled water.
Solution (*b*): 40 grams $Ca(NO_3)_2$, 10 grams KNO_3, 20.56 grams Na_2HPO_4 dissolved in 350 c.c. distilled water.

One hundred cubic centimeters of solution (*a*) and 100 cubic centimeters of solution (*b*) were then added to 9.8 liters of distilled water, and a few drops of ferric chloride solution added.

The seeds were germinated on paraffin-coated wire gauze as described in Bulletin No. 70, Bureau of Soils. When the stems of the seedlings reached a length of 1 inch they were transferred to notched corks and placed in the culture solutions.

The culture solutions were contained in salt-mouth bottles of 250 cubic centimeters capacity, with necks having a diameter of 1¼ inches.

[1] Indiana Experiment Station Bul. No. 170.
[2] Jour. of Agricultural Research, Vol. III., No. 3.

Four seedlings were placed in each bottle. As each experiment was carried on in triplicate this gave a total of twelve seedlings for each treatment.

The first experiment was carried on with aluminum salt and red clover seedlings.

Treatment employed in First Experiment.

1. Nutrient solution (check).
2. Nutrient solution+10 c.c. 1/10 molecular solution of ammonia alum =216 parts per million of Al.
3. Nutrient solution+5 c.c. 1/10 molecular solution of ammonia alum=108 parts per million of Al.
4. Nutrient solution+2 c.c. 1/10 molecular solution of ammonia alum=43 parts per million of Al.
5. Same as No. 2+CaO
6. Same as No. 3+CaO } approximately .5 gram of CaO was added to each bottle.
7. Same as No. 4+CaO

At the end of the first week quite marked differences were noticed in the roots, while the tops of all but the check were about alike. The roots of all but the check and No. 7 (43 p. p. m. Al + CaO) were very much stunted. The roots consisted of the single taproot without root hairs. Four days later the tops began showing differences similar to the roots. The worst seedlings were those in the highest concentration of aluminum, the conditions improving with a decrease in the amount of aluminum present. The presence of the calcium oxide seemed to counteract the toxic effect in a marked degree but not entirely, except in the most dilute solution. At the end of four weeks, when the experiment was discontinued, the differences were the same as noted at the end of the first week, only more pronounced. The seedlings in the bottles containing 216 parts per million (No. 2) and 108 parts per million (No. 3) of the aluminum, respectively, had died at the end of the third week, even in those treated with calcium oxide. The check was in excellent condition and No. 7 (43 p. p. m. + CaO) was fair.

In the second experiment a series of cultures with ferrous sulfate was added, and instead of using calcium oxide to neutralize the toxic action of the aluminum salt the carbonate and sulfate were used in order to avoid the danger of having the nutrient solution become alkaline from the calcium oxide. Enough of the carbonate and sulfate was added to make a saturated solution.

Treatment employed in Second Experiment.

1. Nutrient solution
2. Nutrient solution+$CaCO_3$ } checks.
3. Nutrient solution+$CaSO_4$
4. Nutrient solution+2 c.c. 1/10 molecular aluminum sol.=43 p.p.m. of Al.
5. Nutrient solution+2 c.c. 1/10 molecular Al sol.+$CaCO_3$.
6. Nutrient solution+2 c.c. 1/10 molecular Al sol.+$CaSO_4$.
7. Nutrient solution+1 c.c. 1/10 molecular Al sol.=21.6 p.p.m. of Al.
8. Nutrient solution+1 c.c. 1/10 molecular Al sol.+$CaCO_3$.

9. Nutrient solution+1 c.c. 1/10 molecular Al sol.+$CaSO_4$.
10. Nutrient solution+10 c.c. 1/10 molecular sol. $FeSO_4$=22 p.p.m. of Fe.
11. Nutrient solution+10 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
12. Nutrient solution+10 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.
13. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol. =11 p.p.m. of Fe.
14. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
15. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.
16. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol. =4.5 p.p.m. of Fe.
17. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
18. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.

At the end of three days most of the plants in the higher concentrations of the ferrous sulfate had died. These were replaced, but by the end of the first week these too had died. This failure of the plants to make a start was, I think, in part due to unfavorable weather, there being practically no sunshine during this first week. The same differences as indicated in the first experiment were noticed in this series. Calcium carbonate counteracted the toxic influence of the aluminum salt in both concentrations to a marked degree, but not entirely. In the iron-treated solutions the calcium carbonate had a slightly beneficial effect on No. 14 (11 p. p. m. of Fe), more beneficial on No. 17 (4.5 p. p. m. of Fe), but no effect on the highest concentration (22 p. p. m. of Fe). Calcium sulfate had no effect, the plants being similar to those in the solutions of the same concentrations without the calcium salt. It was also noticed that the seedlings in the solutions containing the iron and aluminum salts without the addition of calcium had a tendency to have stems of a reddish color. The experiment was discontinued at the end of the third week, as most of the plants had died from excessive heat. An extremely hot spell made it impossible to keep the greenhouse cool.

The third experiment was a repetition of the second, with the exception that the highest concentration of the ferrous salt was omitted, and a more dilute one added.

Treatment employed in Third Experiment.

1. Nutrient solution } checks.
2. Nutrient solution+$CaCO_3$ } checks.
3. Nutrient solution+$CaSO_4$ } checks.
4. Nutrient solution+2 c.c. 1/10 molecular aluminum sol. =43 p.p.m. of Al.
5. Nutrient solution+2 c.c. 1/10 molecular aluminum sol.+$CaCO_3$.
6. Nutrient solution+2 c.c. 1/10 molecular aluminum sol.+$CaSO_4$.
7. Nutrient solution+1 c.c. 1/10 molecular aluminum sol. =21.6 p.p.m. of Al.
8. Nutrient solution+1 c.c. 1/10 molecular aluminum sol.+$CaCO_3$.
9. Nutrient solution+1 c.c. 1/10 molecular aluminum sol.+$CaSO_4$
10. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol. =11 p.p.m. of Fe.
11. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
12. Nutrient solution+5 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.
13. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol. =4.4. p.p.m. of Fe.
14. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
15. Nutrient solution+2 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.
16. Nutrient solution+1 c.c. 1/10 molecular $FeSO_4$ sol. =2.2. p.p.m. of Fe.
17. Nutrient solution+1 c.c. 1/10 molecular $FeSO_4$ sol.+$CaCO_3$.
18. Nutrient solution+1 c.c. 1/10 molecular $FeSO_4$ sol.+$CaSO_4$.

As in the previous experiments the roots showed marked differences at the end of the fourth day, while the tops showed no differences until a week had elapsed. The roots of the aluminum and iron treated bottles were very much stunted, and either consisted of only one main taproot without laterals or root hairs, or else quite a number of short thick roots growing from the base of the stem. The laterals only grew about a sixteenth of an inch and then stopped. All of the stunted roots were thicker than the unaffected ones, and despite their much smaller number and shorter length weighed as much as the healthy roots. At the end of six weeks the experiment was discontinued and photographed (Plates I. and II.). The seedlings in the 2.2 parts per million iron solution (No. 16) were almost normal, and where calcium carbonate had been added (No. 17) showed practically no differences from the check. The seedlings in the 4.4 parts per million iron solution (No. 13) made little growth after the first week, but did not die, and where calcium carbonate was added the toxic action was in part overcome. In the 11 parts per million iron solution (No. 10) the plants died at the end of the fourth week. Calcium carbonate in this case seemingly had no effect. As was already noted in the second experiment calcium sulfate had no effect in counteracting the toxic action of the salts. The results with the aluminum salt were exactly similar to those of the first and second experiment.

Summarizing the results of the three experiments we find as follows: —

1. That aluminum sulfate, when present in culture solutions in concentrations greater than 40 parts per million of aluminum, has a very toxic action on clover seedlings.

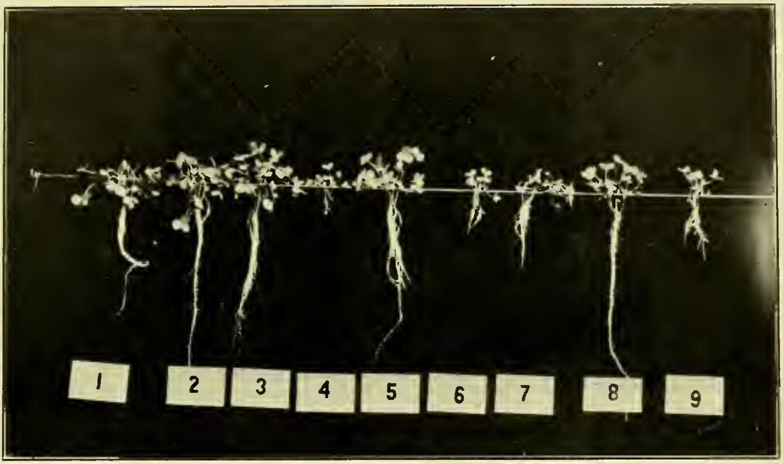
2. That ferrous sulfate when present in culture solutions in concentrations above 4 parts per million of iron exerts a toxic effect on clover seedlings.

3. That this toxic effect of iron and aluminum can, in a large measure, be overcome by the use of calcium carbonate up to a certain point, beyond which it has no effect. Calcium sulfate does not have this beneficial effect. This would seem to indicate that it was not the presence of calcium alone to which the antitoxic action was due, but rather to the combination in which it is present. Calcium in the form of the carbonate precipitates the iron and aluminum in the form of hydroxides, and thus removes them from solution and counteracts their harmful action. The toxic action of the higher concentrations of iron and aluminum, despite the excess of calcium carbonate present, is due, I think, to the solubility of the iron hydroxide. The aluminum hydroxide being less soluble, the toxic effect, even in the most concentrated solutions, is almost entirely counteracted by the calcium carbonate.

4. The idea that the toxicity of iron and aluminum salts is due to the penetration of the salts into the seedlings does not seem to be borne out. That the toxic action seems to be entirely in the first layer or two of cells in the growing portion of the roots is borne out by the following: a microscopical examination[1] shows that the stunting of the roots is due

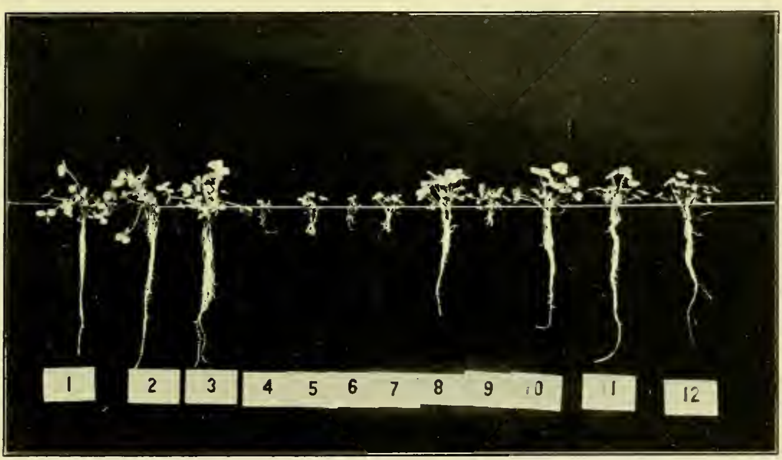
[1] Made by Mr. G. H. Chapman.

PLATE I.



No. 1, Nutrient sol.; No. 2, Nutrient sol.+$CaCO_3$; No. 3, Nutrient sol.+$CaSO_4$; No. 4, Nutrient sol.+2 c.c. Al sol.; No. 5, same as No. 4+$CaCO_3$; No. 6, same as No. 4+$CaSO_4$; No. 7, Nutrient sol.+1 c.c. Al sol.; No. 8, same as No. 7+$CaCO_3$; No. 9, same as No. 7+$CaSO_4$

PLATE II.



No. 1, Nutrient sol.; No. 2, Nutrient sol.+$CaCO_3$; No. 3, Nutrient sol.+$CaSO_4$; No. 4, Nutrient sol.+5 c.c. Fe sol.; No. 5, same as No. 4+$CaCO_3$; No. 6, same as No. 4+$CaSO_4$; No. 7, Nutrient sol.+2 c.c. Fe sol.; No. 8, same as No. 7+$CaCo_3$; No. 9, same as No. 7+$CaSO_4$; No. 10, Nutrient sol.+1 c.c. Fe sol.; No. 11, same as No. 10+$CaCO_3$; No. 12, same as No. 10+$CaSO_4$.

to the arresting of the development or killing of the cells in the growing portion of the root, and not to a poisoning of the entire root system. This is further shown by the large number of short roots which develop from the base of the stem and grow until they touch the toxic solution. The continued growth of the tops after the roots have become stunted also seems to point to the fact that the injury was confined to the growing tips of the roots. If internal, the tops would show the effects sooner than from four to six days after the effect is noticed on the roots. The reason the seedlings finally die is due to a lack of nourishment rather than to a poisoning of the seedling itself. Finally, as Mr. Morse has shown in the preceding article, no appreciable increase in the amount of iron is found in the roots or tops of clover plants whose poor growth in comparison with normal clover plants is assumed to be due to the toxic action of iron.

PHOSPHATES IN MASSACHUSETTS AGRICULTURE; IMPORTANCE, SELECTION AND USE.

WM. P. BROOKS.

SUMMARY.

A. In some of the corn-belt States farmers are advised that phosphorus is the key to permanent and profitable agriculture, and that fine-ground rock phosphates should be used to supply that element.

B. It is pointed out in support of this position that in the agriculture of that section the soils contain relatively little phosphorus and are being rapidly depleted in that element; that they contain practically exhaustless stores of potash; and that by suitable use of lime and the growth of legumes their need for nitrogen can be met.

C. It will be the purpose of this bulletin to show to what extent these statements apply under Massachusetts conditions.

D. It is believed that the facts and results presented will justify the following conclusions: —

1. Massachusetts soils, though not usually supplying as much phosphoric acid as maximum crops require, show a much less signal relative deficiency in that element than corn-belt soils.

2. In our system of agriculture our soils are not being depleted in phosphoric acid, some of the more important reasons being: —

(*a*) The products sold carry relatively little phosphoric acid.

(*b*) Purchased grain and by-products, fed largely on our farms, contain large amounts of phosphoric acid which finds its way to our soils in farm manures, since phosphoric acid, voided in the dung, does not waste appreciably between the stable and the field.

(*c*) The practice of supplementing manures with commercial fertilizers, except where the former as in some types of market gardening are applied in enormous quantities, has been for many years and is now practically universal, and as a rule these commercial fertilizers contain a high proportion of phosphoric acid.

(*d*) Phosphoric acid, even when applied in soluble forms, is fixed and retained in the soil under ordinary soil conditions. This compound is subject to little or no loss by leaching.

3. Experiments in this station and elsewhere in the State indicate that for most of our leading crops potash far more frequently than phosphoric acid is the dominant food requirement. The only prominent exceptions are the crucifers, — cabbage, turnip, etc.

4. Notwithstanding the fact that potash is usually the more important of the two the use of phosphoric acid in our agriculture is generally profitable, as will be shown by the results of experiments presented.

5. It will be shown that when both dissolved and fine-ground natural rock phosphates are annually applied the former have given both the larger and the more profitable crop increases over a long series of years.

6. It will be shown that although more than 1,600 pounds per acre of phosphoric acid in the form of natural rock phosphates have been applied in a series of experiments extending over eighteen years, the yields on these plots at present are even more inferior to the yields on plots receiving the same amount of phosphoric acid in the more soluble phosphates than in the earlier years of the experiments.

7. It will be shown that the dissolved phosphates have exerted certain highly important secondary effects, among the more important being: —

(*a*) Stimulation to rapid early growth both of root and top, which secures, among other important advantages, sufficient root growth to more surely draw from the soil from the start both the water and the food needed, and ability better to resist insect injuries.

(*b*) Earlier and more perfect maturity, which may mean a much higher price for the product, as in market gardening, or immunity from frost damage in the case of late ripening crops or cold summers.

(*c*) It will be pointed out that the work of others appears to demonstrate the following additional secondary effects following the judicious use of dissolved phosphates: increased tillering of grain and grasses; increased availability of some important soil constituents; greater activity of nitrifying organisms in the soil; and larger soil gain in atmospheric nitrogen as a result of increase in assimilation of this element by micro-organisms in the soil.

8. Results will be presented which indicate that reasonable use of an acid phosphate does not increase the necessity for application of lime, — indeed, that in the experiments cited it appears to have had the opposite effect.

9. The final conclusions drawn from a consideration of all the facts and results discussed may be thus stated: —

(*a*) In Massachusetts agriculture it usually pays to use phosphoric acid containing fertilizers in at least moderate amounts.

(*b*) The more soluble phosphates are better adapted to our needs than the fine-ground natural rock phosphates. Among materials ordinarily used for supplying phosphoric acid only, usually most available and satisfactory, are acid phosphate, dissolved bone black and basic slag meal. Almost all mixed and special complete fertilizers contain liberal amounts of soluble and available phosphoric acid. Other sources of phosphoric acid in soluble or fairly available forms are dissolved bone, bone meals, tankage and fish, all of them also supplying some nitrogen.

INTRODUCTION.

During the last few years the system in the use of fertilizers, and more particularly the practice of depending upon fine-ground rock phosphate, so strongly advocated by Dr. Cyril G. Hopkins and some others, and based largely upon experimental results obtained by Dr. Hopkins in Illinois, have been prominently advocated in some of our agricultural papers for adoption under Massachusetts conditions. At the present time a company interested in the sale of fine-ground natural phosphate is carrying on an active propaganda which aims to convince our farmers, fruit-growers and gardeners that the chief fertilizer requirement of their soils is phosphoric acid, and that fine-ground natural rock phosphate is the material best adapted to their needs. The literature sent out by this company is being distributed everywhere. The conclusions urged are supported by numerous quotations, figures and illustrations drawn chiefly from the publications of experiment stations in the great central valley — the corn-belt — of the United States. This matter is so marshalled and presented that the argument seems likely to produce a strong impression; it may carry conviction to many minds.

It is of the utmost importance to our agriculture that the extent to which the teachings of Dr. Hopkins (the father of the system) are applicable under Massachusetts conditions should be known. If he be right, then certainly our farmers are buying unnecessary fertilizer elements, and needlessly paying the fertilizer manufacturers to render the phosphoric acid of the rock phosphates soluble and available. The adoption here of the Hopkins system, if sound, must mean a more profitable agriculture.

It seems, therefore, highly important that the whole question should be most carefully studied. Local conditions must be compared with corn-belt conditions; the results of local experiments must be presented and studied. It is well known that practice must usually vary with locality. A practice wise in one section is often most unwise in another where conditions are different.

The general features of the Hopkins system are stated on page 159 of his book on "Soil Fertility and Permanent Agriculture," from which the following quotation is taken: —

> For practically all of the normal soils of the United States, and especially for those of the Central states, there are only three constituents that must be supplied in order to adopt systems of farming that, if continued, will increase, or at least permanently maintain, the productive power of the soil. These are *limestone, phosphorus* and *organic matter*. The limestone must be used to correct acidity where it now exists or where it may develop. The phosphorus is needed solely for its plant-food value. The supply of organic matter must be renewed to provide nitrogen from its decomposition and to make available the potassium and other essential elements contained in the soil in abundance, as well as to liberate phosphorus from the raw mineral phosphate naturally contained in or applied to the soil.

The value of an application of lime in some form to many of our soils is fully recognized. It is frequently an essential for successful crop production. The importance of organic matter is admitted. It is useful not alone in promoting the availability of such elements as potassium and phosphoric acid, and as a source of nitrogen to the growing crop, but also for the maintenance of satisfactory soil texture. Without a fair proportion of such matter in the soil good tilth is impossible, and on the lighter soils, especially, extreme injury to crops in periods of drouth is a certainty. These phases of the general subject of fertility will not be discussed in this paper. It is proposed simply to study the question of the applicability of the Hopkins theory in relation to the use of phosphorus [1] to Massachusetts conditions.

The quotation above cited makes it apparent that Hopkins regards the application of fertilizer nitrogen or potash under normal soil conditions as superfluous, and that he believes that a suitable application of phosphorus (in addition to lime and organic matter) is all that will be found needful.

The conclusions of Dr. Hopkins are further emphasized and the reasons therefor more clearly brought out by the following quotation from the book above referred to: [2] —

> Phosphorus is the only element that must be purchased and returned to the most common soils of the United States. *Phosphorus is the key to permanent agriculture on these lands.* To maintain or increase the amount of phosphorus in the soil makes possible the growth of clover (or other legumes) and the consequent addition of nitrogen from the inexhaustible supply in the air; and, with the addition of decaying organic matter in the residues of clover and other crops and in manure made in large part from clover hay and pasture and from the larger crops of corn and other grains which clover helps to produce, comes the possibility of liberating from the immense supplies in the soil sufficient potassium, [3] magnesium, and other essential abundant elements, supplemented by the amounts returned in manure and crop residues, for the production of large crops at least for thousands of years; whereas, if the supply of phosphorus in the soil is steadily decreased in the future, in accordance with the past and present most common farm practice, then poverty is the only future for the people who till the common agricultural lands of the United States.
>
> And this does not refer to the far-distant future only, for the turning point is already past on most farms in our older states and on many farms in the corn belt; and lands that have passed their prime with sixty years of cultivation will decrease rapidly in productive power and value during another sixty years of similar exhaustive farm practice.

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[1] Phosphorus is the element of value as plant food supplied by the compound phosphoric acid, which is the most valuable constituent of acid phosphate, dissolved bone black, basic slag meal, fine-ground rock phosphates and raw and steamed bones. In the publications of this experiment station and in agricultural literature in general the name "phosphoric acid" is usually used. Figures indicating the amounts of phosphoric acid can be converted into approximate equivalents in phosphorus by multiplying by .44; and figures for phosphorus into substantial equivalents in phosphoric acid by multiplying by 2.3.

[2] Hopkins' "Soil Fertility and Permanent Agriculture," page 183.

[3] Potassium is the name of the element of plant-food value in the compound potash or potassium oxid, under which names in our station publications and in agricultural literature in general this plant food is usually referred to. Figures for potash (or potassium oxid) can be converted into approximate equivalents in potassium by multiplying by .83; figures for potassium can be converted into potash (or potassium oxid) by multiplying by 1.2.

Some of the more essential among the reasons which Dr. Hopkins here advances in support of his system of dependence upon application of fine-ground rock phosphate are the following: —

1. Phosphorus is already dangerously deficient in the soils of our older States, and is rapidly becoming more so.

2. There are, on the other hand, in the most common soils of the United States, "immense supplies of potassium" (and other essential elements), — enough, "supplemented by the amounts returned in manures and crop residues," for the production of "large crops at least for thousands of years."

3. If limestone be first applied to neutralize existing acidity, and fine-ground rock phosphate thereafter abundantly applied, the soil will become fitted for the growth of clover (or other legumes).

4. The growth of clover makes possible the acquisition of nitrogen from the air, so that this element need not be purchased.

5. If organic matter in the residues of clover and other crops, and in manure made largely from clover hay and pasture, be abundant in the soil, the phosphoric acid of the natural rock phosphates will be rendered available with sufficient rapidity for large crop production.

6. The use of rock phosphate instead of acid phosphate or (by fair implication I think) other sources of phosphoric acid means a large saving in money outlay.

7. The results of numerous experiments which it is held prove the soundness of these conclusions are presented in the book above referred to, in bulletins of the Illinois Experiment Station, as well as in other writings by Dr. Hopkins, who in the book and to some extent elsewhere also quotes results obtained in several other experiment stations.

It is proposed to consider these propositions, as to the degree of their applicability to the conditions of our agriculture, in the light of such experimental work bearing upon them as has been done in this experiment station. The writer would call particular attention to the fact that this study is not entered upon because of any doubt of the validity and soundness of Dr. Hopkins's conclusions and advice in so far as they relate to the conditions of the corn-belt. He is at the same time an able investigator and a tireless worker. His work has been of enormous value to the farmers of the corn-belt.

Among the reasons enumerated the first and second, both of which relate to the composition of the soil, are most conveniently considered together.

RELATION OF MASSACHUSETTS AGRICULTURE TO SOIL COMPOSITION, AND RESULTS OF CHEMICAL ANALYSES.

Under the system of agriculture most common in the corn-belt States phosphoric acid is largely carried away from the farm in products sold. Wheat, corn, oats, beef, mutton, pork and milk are all rich in this compound. In view of this fact it is not surprising that, as Dr. Hopkins points out, the supply of phosphorus in the soils has decreased steadily under the system of agriculture pursued, and is now steadily decreasing under the most common farm practice.

Conditions in Massachusetts are widely different: —

1. The principal products sold from our farms are hay, vegetables, fruit and milk. The latter is the only product which carries away much phosphoric acid, and the proportion in this is small. The milk of 20 cows for one year (6,000 pounds each) will contain only about 100 pounds of phosphorus.

Timothy hay contains over four times as much potash as phosphoric acid; medium red clover, five times; cabbages, four times; potatoes, six times; and other vegetables in about the same proportion. In fruits the amount of potash is about six times the amount of phosphoric acid. If we reduce these figures to the basis of phosphorus and potassium used by Hopkins the comparison is yet more striking, for in the products chiefly sold from Massachusetts farms the amount of potassium carried away will run from eight to ten times the amount of phosphorus.

2. Many farmers use a large amount of purchased feeds, nearly all of which are very rich in phosphoric acid. This reaches our soils in the manures from our cattle and horses. In the oats fed on the average to a pair of work horses in one year there are about 40 pounds of phosphoric acid, while in the purchased feeds for a herd of 20 cows it is probable that on the average we shall find 600 pounds of phosphoric acid.

3. The potash of animal excrements is voided mostly in solution in the urine (on the average, about four-fifths of the total). The phosphoric acid, on the contrary, is voided almost exclusively in the dung in insoluble forms. Under ordinary systems of stabling our live stock and saving manures the potash, therefore, is subject to loss in much greater degree than the phosphoric acid.

4. That the crops we principally grow take from our soils far more potash than phosphoric acid has been made apparent from what has been said of the relative proportions of these two elements in the products sold. Essentially the same relation holds for the products mainly consumed on the farm.

5. In our agriculture we have used commercial fertilizers largely for at least forty years. With few exceptions these contain much larger proportions of phosphoric acid than of potash. It is impossible to present exact figures, but it is the writer's judgment that on the average twice as much phosphoric acid as potash has been generally applied in the fertilizers used.

Does it seem likely, in view of the facts stated, that our soils are being especially depleted in phosphoric acid? This can be true only if the phosphoric acid is subject to loss from our soils under the influence of natural agencies in unusually large proportion. That this is the case is highly improbable. Phosphoric acid cannot escape into the air; and in the soil, even though soluble when applied, it soon enters into new combinations insoluble in water. Experiment shows that under normal conditions there is but very little loss of phosphoric acid in drainage waters.

Does it, then, seem probable that in Massachusetts agriculture, as in that of the corn-belt, phosphoric acid is the only mineral element which need be supplied?

The principal conditions having a bearing upon the tendency in our farm practice may be thus restated: —

1. In products sold from five to six times as much potash as phosphoric acid is carried away.
2. We bring in large amounts of phosphoric acid in purchased feeds.
3. Potash is far more subject to waste from animal excrements than is phosphoric acid.
4. The products of our fields, gardens and orchards all require far more potash than phosphoric acid.
5. In the commercial fertilizers so extensively used far more phosphoric acid than potash has been for years applied to our soils.

The tendency in our agriculture, therefore, must be to disproportionate consumption of potash and not of phosphoric acid.

If, however, the stock of phosphoric acid in our soils is extremely small, — far less than the stock of potash, — then it may nevertheless be true that phosphoric acid rather than potash is the principal fertilizer requirement in our agriculture.

A study of the results of such analyses of our soils as have been made is essential to the formation of a conclusion upon this point.

Composition of Massachusetts Soils.

This experiment station has published the results of analyses of 194 soil samples[1] taken in this State. These samples have come from 79 different towns and represent practically all our leading soil types. All the counties of the State except Dukes and Nantucket — the island counties — are represented.

The analyses reported have been made by the methods recommended by the American Association of Official Agricultural Chemists. These methods do not show the totals of any of the plant-food elements except nitrogen, but only the proportion which is dissolved in an acid of definite strength used at a definite temperature for a definite length of time. The results are believed to represent at least the percentages likely to become available within a generation. The table shows the average results by counties and for the entire State.

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[1] See twenty-third annual report, Massachusetts Agricultural Experiment Station, p. 339.

Soil Analyses.

County.	Number of Towns represented.	Number of Samples.	N.	P_2O_5.	K_2O.	CaO.
Barnstable,	2	2	.205	.145	.170	.695
Berkshire,	3	8	.286	.242	.452	.856
Bristol,	5	16	.198	.147	.180	.643
Essex,	6	13	.518	.251	.295	.544
Franklin,	8	16	.352	.212	.306	.718
Hampden,	7	23	.253	.390	.310	.837
Hampshire,	6	21	.259	.215	.236	.704
Middlesex,	15	33	.256	.143	.213	.618
Norfolk,	8	19	.276	.187	.187	.916
Plymouth,	7	17	.312	.175	.197	.655
Suffolk,	1	9	.213	.140	.247	.416
Worcester,	11	17	.258	.250	.295	.713
Average (194 samples),	79	194	.282	.214	.252	.669

Examination of the table shows that there are but two counties in which the percentage of potash exceeds that of phosphoric acid by any considerable amount, — Berkshire and Franklin. In Berkshire there is about 90 per cent. more potash than phosphoric acid; in Franklin, about 44 per cent. more. The soils analyzed from Berkshire County have all come from three towns, — Lenox, Washington and North Adams. Those from the two former are of about the usual character, but those from North Adams are unusually rich in potash.

Eight different towns are represented in the Franklin analyses. The samples excessively rich in potash are more generally distributed. Nearly every town shows samples in which the per cent. of potash is nearly or quite double that of phosphoric acid.

The average for the State shows the proportion of the two compounds, phosphoric acid and potash, to be nearly equal, — .214 per cent. phosphoric acid and .252 per cent. potash. These figures pertain to the surface soil, the depth of which, of course, varies greatly. Assuming, however, that the average depth is 8 inches, and that the average weight of surface loams is about 80 pounds to the cubic foot, the total number of pounds of surface soil in an acre is approximately 2,300,000. The table below shows in round numbers the number of pounds each of phosphoric acid and potash in an acre of the average composition of Massachusetts soils, and for comparison the number of pounds, in most cases as indicated by analyses made here, of each of these compounds contained in the supposed product of one acre of some of our leading crops: —

	Pounds in One Acre Surface Soil (8 Inches).	Corn; Grain, 75 Bushels; Stover 3 Tons.	Potatoes, 300 Bushels.	Timothy Hay, 2.5 Tons.	Cabbages, 20 Tons.	Onions, 800 Bushels.	Tomatoes,[1] 500 Bushels.	Asparagus, 6,000 Pounds.
Phosphoric acid (pounds),	5,000	47.26	13.68	17.10	8.00[2]	29.12	21.00	6.40
Potash (pounds), . .	5,800	107.28	91.80	73.00	136.00	74.88	105.00	20.00

[1] From Van Slyke, "Fertilizers and Crops."

[2] Most published analyses are higher for this constituent.

The totals for phosphoric acid and potash in the surface 8 inches of the average Massachusetts soil (as determined by analyses which have been made here), and shown in this table, may be compared with the requirements of large crops, also shown in the table. This comparison, made by dividing the totals in the soil by the totals in the crops, shows that there is phosphoric acid enough in the soil for from 92 to 800 crops. The potash is sufficient for from 42 to 290 crops. It is, of course, not the writer's belief that without manure or fertilizer profitable crops can be grown for the number of years which this method of calculation shows; for long before the supply of phosphoric acid or potash should become exhausted the yield would fall below the limit of profitable production; indeed, on many of the soils included in arriving at the averages presented, profitable production without the addition of both phosphoric acid and potash in manures or fertilizers is already impossible. Plants cannot "lick the platter clean."

It is generally known that the root system is by no means confined to the surface soil. Where the water table allows, most crops feed to some extent to the depth of several feet. The relation of total phosphoric acid and potash in surface soil to the amount in crops is nevertheless of interest in connection with our consideration of the applicability of the Hopkins theory of farm fertility under our conditions. The facts cited strengthen the writer's contention that potash rather than phosphoric acid is the key to profitable agriculture in most cases in Massachusetts.

RELATIVE NEED OF PHOSPHORIC ACID AND POTASH.

Experimental Results.

Full details will not be given in this paper. They will be brought together for publication in a bulletin on "Potash Requirements in Massachusetts Agriculture." Detailed reports on results from year to year in most of the experiments to which reference will here be made have appeared in bulletins and annual reports of the station.

The Potato. — The experiments which have been in progress for so many years for comparison of different phosphates, and those for the comparison of different potash salts, make it possible to compare the effects of phosphoric acid and of potash. In each case the average increase of all the plots receiving in the one case phosphoric acid, and in the other potash, is compared with the average of the no-phosphoric acid or the no-potash plots. There are 3 no-phosphate plots and 10 receiving phosphate in the one experiment; and in the other there are 5 plots which receive no potash and 35 which do receive it. The table shows the results: —

Potatoes — Relative Effects, Phosphoric Acid and Potash.[1]

	Average Yield per Acre (Bushels).	Increase.	
		Per Acre (Bushels).	Per Cent.
Fourteenth Year (1910).[2]			
No-phosphate plots,	248.4	7.7	3.09
Phosphate plots,	256.1		
Tenth Year (1907).[3]			
No-potash plots,	197.96	57.21	29.39
Potash plots,	255.17		
Sixteenth Year (1913).[4]			
No-potash plots,	41.20	49.47	120.55
Potash plots,	90.67		

The station has carried out a few co-operative soil tests with potatoes as the crop. The results of four of these, located respectively in Marblehead, Hadley, Concord and Amherst, have been averaged, and in so far as they serve to indicate the relative need for phosphoric acid and potash for this crop the averages are here presented.[5] As is customary in soil test work[6] each plant-food element is used by itself, in combination with each of the others and in combination with both of the others. Averages will be presented showing the results of the two elements under comparison when used alone, as well as when each is used in connection with both the others. The latter figures, as will be understood, are the more significant, as each element may more fully show its effect and importance when all others are present in sufficient amounts.

[1] The number of the years as given indicates length of time the fertilizer experiment had continued. Crops have always been rotated.

[2] For details see twenty-third annual report, Part I., pp. 42-44.

[3] For full details see twentieth annual report, Part I., pp. 39-42.

[4] From unpublished results. The very small yield in this year was due chiefly to seasonal peculiarities.

[5] For details see Bulletin No. 18, Hatch Experiment Station.

[6] The plan followed in this soil test work, as well as in all the other similar work referred to in this bulletin, is given in Bulletin No. 9 of the Hatch Experiment Station.

Average Increases per Acre in Potato Crop (Bushels).

	Produced by the Use of —	
	Phosphoric Acid.	Potash.
When used alone,	8.68	43.54
When used in complete fertilizer,	7.94	60.39

The Corn Crop. — The corn crop has been used in soil test work in this station far more extensively than potatoes, and the results bear very decisively upon the question of the relative necessity of application of phosphoric acid and potash in our agriculture. In the experiments upon the south soil test acre, which have been continued from 1889 to the present time, ten corn crops have been grown.[1] The average results are shown in so far as they bear upon the question under discussion in the tables which follow: —

Average Increase per Acre in Nine[2] Corn Crops (South Soil Test).

	Produced by the Use of —			
	Phosphoric Acid.		Potash.	
	Grain (Bushels).	Stover (Pounds).	Grain (Bushels).	Stover (Pounds).
When used alone,	1.7	—39.0	26.3	2,043.3
When added to nitrate,	2.7	212.0	20.8	1,748.8
When added to the other,[3]	6.3	534.4	30.9	2,616.7
When used in complete fertilizer,	14.2	911.7	32.5	2,447.2

The crop in this field in 1913 was corn following crimson clover sown in 1912 and plowed under in the spring of 1913. The crop where phosphoric acid alone had, then, been yearly applied for twenty-five years (lime in 1899, 1 ton per acre; 1904, 1 ton per acre; and 1907, ½ ton per acre excepted) was at the following rates per acre: grain, 11 bushels (10 of which were soft), and stover, 2,180 pounds. Where potash had been used alone for the same number of years and under the same conditions the yield was grain, 52.6 bushels (7.7 of which were soft), and stover, 4,360 pounds.

[1] For full reports see bulletins and reports of the Massachusetts Agricultural Experiment Station (known as the "Hatch" Experiment Station, 1888 to 1906).

[2] The crop for 1910 is not included in figuring averages, since through accident the appropriate fertilizer was not applied in that year to one plot.

[3] That is, phosphoric acid added to potash or potash added to phosphoric acid.

The comparative results with corn surely show in a most striking way the paramount importance of potash for that crop on this soil, while it is brought out with equal clearness that the effect following the application of phosphoric acid is comparatively insignificant. It is pertinent here to call attention to the fact that the field in which these experiments have been tried is of the same character, both as to geological origin and past treatment, as the soils for which analyses showing extraordinary quantities of potash both in surface and subsoils have been made. An analysis of this soil has shown it to contain .38 per cent. acid soluble potash in the surface soil, which undoubtedly means at least 40,000 pounds total potash in the first 3 feet in depth to the acre.

It will be of interest here to inquire whether similar results should be anticipated with the corn crop in other parts of the State. The station has conducted thirty-one soil test experiments with corn in different parts of the State, every county, except Dukes and Nantucket (islands), and most of the leading soil types being covered. With hardly an exception the results have been of the same general character with those on our own grounds, and in full agreement with those as to general teaching. A few averages only will be here presented.[1]

Average per Acre in Thirty-one Corn Crops (Soil Tests).

	Increase produced by the Use of —			
	Phosphoric Acid.		Potash.	
	Grain (Bushels).	Stover (Pounds).	Grain (Bushels).	Stover (Pounds).
When used alone,	.75	8.84	10.85	902.04
When used in complete fertilizer,	5.91	265.72	12.75	1,402.57

These results, while not demonstrating so great a degree of superiority for the potash as compared with the phosphoric acid as our home experiments, still indicate that it, rather than phosphoric acid, is the element chiefly required.[2]

The Hay Crop. — A good basis of comparison of the effects, respectively, of phosphoric acid and potash upon this crop is afforded by the results upon the fields devoted to comparative trials of different phosphates (phosphate field) and of different potash salts (field G). The hay crop

[1] For details see Bulletins Nos. 9 and 18, Hatch Experiment Station, and annual reports.

[2] In our soil test experiments dissolved bone black or acid phosphate at the rate of 320 pounds per acre has always been used as the source of phosphoric acid, and muriate of potash at the rate of 160 pounds per acre as the source of potash. It is recognized that in using these amounts we are applying potash at a heavier rate per acre than phosphoric acid, — about 80 pounds to about 54 pounds. It is pointed out, however, that while the ratio of application of phosphoric acid to potash is as 1 : 1.5, the ratio of these elements in the crop is 1 : 6.7, so that phosphoric acid is applied in much the larger proportion as compared with the crop requirement.

included in the rotations which have been followed on both has included mixed timothy, redtop and red and alsike clovers. On the phosphate field materials furnishing nitrogen and potash are annually equally and liberally applied to all plots. There are 3 no-phosphate plots and 10 receive phosphoric acid. On field G there are 5 similar series of plots, each series including 1 no-potash plot and 7 receiving potash. All plots annually receive materials furnishing equal nitrogen and phosphoric acid. Average results only are here presented.[1]

Effects of Phosphoric Acid on the Hay Crop (Phosphate Field).

Year.	Yields per Acre (Pounds).				Gain.			
	No Phosphate.		Average Phosphate.		Per Acre (Pounds).		Per Cent.	
	Hay.	Rowen.	Hay.	Rowen.	Hay.	Rowen.	Hay.	Rowen.
1906, . . .	6,720	1,867	7,308	1,944	588	77	8.7	4.1
1907, . . .	7,933	333	8,612	480	679	147	8.5	44.0

Effects of Potash on the Hay Crop (Field G).

Year.	Yields per Acre (Pounds).				Gain.			
	No Potash.		Average Potash.		Per Acre (Pounds).		Per Cent.	
	Hay.	Rowen.	Hay.	Rowen.	Hay.	Rowen.	Hay.	Rowen.
1909, . . .	5,744	680	6,413	1,561	669	881	11.6	129.6
1910, . . .	6,240	698	6,829	1,685	589	987	9.4	141.4
1911, . . .	3,040	1,440	4,283	1,908	1,243	468	40.9	32.5

It will be noted that neither phosphoric acid nor potash produced a large increase in the first cut of the season ("hay") except in one year, 1911, when the potash appeared greatly to improve the crop. Neither, as is well understood, is the dominant requirement for either timothy or redtop which predominate in the first cut. The increase in hay produced by the potash is, however, greater even when lowest than that produced by the phosphoric acid at its best.

The far greater proportional increase in the rowen crop produced by the potash is explained by its relation to clover, which cannot be successfully produced in our soils without it. The lesser increase in the

[1] For details see annual reports for 1907, 1908, 1910, 1911 and 1912. The great variations in yield, even with full fertilization in different years, were doubtless due chiefly to seasonal variations in rainfall.

rowen crop in 1911 is doubtless explained by the fact that the original clover plants (biennial or short-lived perennials) had then for the most part died, that being the third year since seeding.

The soil test work of the experiment station affords another opportunity of comparison of the effects of phosphoric acid and potash on the hay crop (as in the other experiments with hay referred to made up of timothy, redtop and clovers). Hay has occupied our south soil test acre six years, but in only four of them was a second or rowen crop cut. The soil is rather light, the fertility only medium, even on the plots receiving a complete fertilizer, and in hot, dry summers the second growth is light.

Average Increase in Six Hay and Four Rowen Crops (South Soil Test) (Pounds).

	Produced by the Use of —			
	Phosphoric acid.		Potash.	
	Hay.	Rowen.	Hay.	Rowen.
When used alone,	—66.7	78.8	407.1	489.5
When used in complete fertilizer,	463.3	367.5	721.7	607.5

The striking superiority in effects produced by the potash is at once apparent.

Results obtained in soil tests in different parts of the State are similar in kind, but the superiority of the yields on potash is much smaller than on our home grounds, — a consequence, in my judgment, at least in large measure, of the fact that the soils were undoubtedly in many cases acid. These experiments were all tried before the fact that so many of our soils are in need of lime was fully appreciated (1892 to 1895).

Asparagus. — We have definite data on asparagus. In our substation in Concord for asparagus investigation both phosphoric acid and potash are applied — in combination in each case with the other two plant-food elements — under conditions which make it possible to determine the specific effects. Each of the plots for which data are given has been under uniform treatment for seven years. The phosphoric acid is applied in the form of acid phosphate, and the potash in the form of muriate. The table presents the relative results of the application of phosphoric acid and potash for 1914 (the seventh year).

Asparagus — Comparative Results, Phosphoric Acid and Potash, 1914. (*Yield and Increase per Plot.*[1])

Acid Phosphate.

Amount applied per Plot (Pounds).	Yield.		Increase.	
	Pounds.	Ounces.	Pounds.	Ounces.
None,	404	4	–	–
15.00,	420	6	16	2
22.50,	436	15	32	11
30.00,	436	6	32	2

Muriate of Potash.

Amount applied per Plot (Pounds).	Yield.		Increase.	
	Pounds.	Ounces.	Pounds.	Ounces.
None,	366	11	–	–
8.67,	408	6	41	11
13.00,	478	15	112	4
17.33,	458	8	91	13

[1] One-twentieth of an acre.

The objection may possibly be raised — as in the case of the soil test work, in which some of the results cited for corn and other crops were obtained — that the potash being used at a greater rate per acre than the phosphoric acid, the comparison may be misleading. If, however, phosphoric acid be the element present *in minimo*, certainly even a very moderate application should give a notable increase in crop; and further, if it be the element *in minimo* and our application be too small, no amount of potash could exercise much effect, for it cannot take the place of phosphoric acid.

Yet further, in view of the facts that the ratio of phosphoric acid to potash is 1 to 3 in the crop (spring shoots), while in our applications the ratio between the two is 1 to 1.9, it can scarcely be urged that we are using phosphoric acid in disproportionately small amounts.

Soy Beans, Oats and Rye. — Soil test experiments with soy beans have given much larger increases in crop with potash than with phosphoric acid. Similar experiments with oats and rye have shown a relatively small superiority for the potash. Neither is the dominant element for these crops.

Cruciferæ. — Absolutely the only crops which have ever responded in our soil test work more largely to an application of phosphoric acid than to one of potash are those belonging to *Cruciferæ*, such as the cabbage, Swedish turnip and white mustard.[1] This is best shown in the results obtained on the north soil test in 1896 with cabbages. With Swedish turnips in that year the two materials gave equal increases.

Cabbages and Turnips — Increases per Acre (North Soil Test) (Pounds).

	Produced by the Use of —			
	PHOSPHORIC ACID.		POTASH.	
	Cabbage.	Turnip.	Cabbage.	Turnip.
When used in complete fertilizer, . . .	20,890	10,400	14,400	10,400

The experimental results presented appear to prove that potash application may usually be depended upon to give greater increases in most of our more important crops than phosphoric acid application. The figures given very conclusively demonstrate this for our station grounds, and, with little less conclusiveness, for widely divergent soil types in most parts of the State for potatoes, corn, hay (especially the second cut, which is usually chiefly clover) and soy beans. We know that the requirements of other legumes, including alfalfa, are in general similar to those of clovers and soy beans. We know, also, that potash application exercises a far greater effect in determining the yields of most of our fruits and garden crops than phosphoric acid application.

In view of the fact so clearly demonstrated by the figures which have been presented for our most important crops, no further argument would seem to be needed to demonstrate that phosphoric acid is not the key to "permanent" (successful and profitable) "agriculture" in Massachusetts. It is true, indeed, that our soils and subsoils contain less phosphoric acid than potash, but it is also true that under our system of agriculture the phosphoric acid has not apparently been undergoing exhaustion, and that it is not now being depleted. It is not true for most crops that phosphoric acid is the element present in our soils *in minimo*. Potash for many is the element which determines the crop more largely than any other element applied. Without the application of potash in available form, either in manures or fertilizers, the profitable production of most crops is impossible.

On the other hand, profitable crops of most kinds may be produced for a time without application of phosphoric acid. This, indeed, is not a practice which can be recommended. Such a system should be followed as will at least maintain the proportion of phosphoric acid at present existing in our soils. To reduce the percentage below its present level would for most soils and crops be a mistake.

[1] For discussion of this subject see Bulletin No. 58, Hatch Experiment Station.

Massachusetts farmers, then, should apply phosphoric acid for most crops, but certainly not to the exclusion of potash. However abundant the phosphoric acid it will not take the place of potash. However largely applied it will not reduce the necessity for the application of potash for most crops. It has no direct influence, so far as known, on the extent to which inert soil potash is rendered available. Since, however, without doubt some phosphoric acid should be applied in our ordinary farm and garden practice, the question whether, as Hopkins and his disciples believe, fine-ground rock phosphate is the best form is important. Two series of experiments in this station throw light upon the question. Both have been carried out on medium silt loams containing an average per cent. of humus and possessing excellent physical characteristics.

EXPERIMENTS FOR COMPARISON OF DIFFERENT PHOSPHATES.

The two sets of experiments designed to show the comparative effectiveness and value in agriculture of different phosphates which have been conducted here have both extended over a considerable number of years, and the conditions have been, so far as can be judged, as favorable to the activity of the more insoluble materials as will usually be found in our upland soils. The soil structure and texture are such as to favor optimum moisture conditions, and at the same time adequate aeration and good tilth. In both fields the soils were at the outset moderately acid. In the first mentioned lime at the rate of a ton to the acre was applied once during the progress of the experiment. In the other two, similar applications of lime have been made. The quantity in both fields was considerably short of that required to completely neutralize the free acids present.

In both experiments most of the principal crops common in our agriculture have found a place, and some of them for several years. In neither series of experiments has any manure been applied. In both, chemical fertilizers containing nitrogen and potash in quantities believed to be adequate for large crops have been equally applied to all plots.

In one series of experiments the basis of comparison of the phosphates used was "equal money's worth;" in the other, "equal phosphoric acid."

Comparison of Phosphates on the Basis of Equal Money's Worth.

A full account of this experiment has already been published.[1] Detailed reference to it at this time, therefore, is unnecessary. I may go further and say that any reference to the results of this series of experiments might lead to the formation of absolutely misleading conclusions. The experiment was clearly not of such a character as to afford a fair basis of comparison between the more soluble phosphates and the rock phosphates, for, as is shown by our other series of experiments as well as

[1] Fourteenth annual report, Hatch Experiment Station, pp. 24–28.

by the work of others, the more soluble phosphates exert special influences which are highly important as a result of their relatively soluble condition when applied. Any advantage which may be connected with this relatively high degree of solubility is of course largely lost, in so far as the residual phosphoric acid they contain is concerned, because of the change in the soil which converts this phosphoric acid into a much less soluble form. The true way to use dissolved phosphates, as is well understood, is not to apply at any one time in great excess of the requirements of the immediately succeeding crops, but to apply as a rule annually, in the case of hoed crops at least, in quantities more nearly equal to the immediate crop requirement.

In this series of experiments the different phosphates under comparison (dissolved bone black, basic slag meal, South Carolina rock phosphate, Florida rock phosphate and Mona guano) were applied during only four years. The experiment was continued twelve years. During this long period of time the basic slag meal gave the greatest total crop yield; the South Carolina rock phosphate ranked next, but was followed so closely by the dissolved bone black that the difference was quite insignificant in spite of the fact that the latter was used in a manner so absolutely irrational, and applied in quantity furnishing only about one-third as much phosphoric acid as was applied in the South Carolina rock phosphate. The yields on the Mona guano and Florida rock phosphate, especially on the latter, were materially below those obtained on the dissolved bone black.

It should, perhaps, be pointed out further that this experiment was continued a number of years after the crop yield on all plots had sunk below the profitable level, while there still remained in the soil of the plots which had received the rock phosphates more than two-thirds of the large amount of phosphoric acid which had been applied. At the same time, the phosphoric acid which had been applied in the dissolved bone black had nearly all been carried away in the crops.

Phosphates compared on the Basis of Equal Annual Applications of Phosphoric Acid.

This series of experiments was begun in 1897 and is still continued. We now have the results of eighteen years. The soil is a medium silt loam which had been in grass a number of years previous to being plowed for the experiment. The soil varies somewhat in physical character in different plots, but as the variation is progressive from one end of the field to the other, and the arrangement includes a no-phosphate plot at either end and one in the middle, each phosphate being compared only with the two no-phosphate plots between which it lies, and each of these being given a weight inversely proportional to its distance, it is not believed that any injustice is done to any of the phosphates in the results as presented. The more soluble phosphate plots are at the end of the field where the soil is the more heavy.

The area of the plots is one-eighth acre, — thirteen in all.

Annual Application to All Plots.

	Rate per Acre (Pounds).
High-grade sulfate of potash,[1]	300
Nitrate of soda,[2]	364
Sulfate of ammonia,	100
Hoof meal[3] (to all no-phosphate and mineral phosphate plots),[4]	102

The various forms of bone meal all contain organic nitrogen; the steamed bone usually most. To equalize conditions hoof meal is applied to each in such quantities as are required to bring the total organic nitrogen to the same amount as is furnished by the hoof meal on the other plots.

Plant-food Elements applied.

In the materials used the annual application of plant-food elements has varied somewhat with slightly varying composition of materials. One important change has been made, viz., a 50 per cent. increase in the nitrate nitrogen and in the actual potash in 1901. The annual application per plot has been substantially constant since that date, as follows: —

Plant Food applied Annually (Pounds).

	Per Plot.	Per Acre.
Nitrogen,	11.4	91.2
Potash,	19.0	152.0
Phosphoric acid,	12.0	96.0

General Treatment.

The entire field received an application of hydrated lime at the rate of one ton per acre in 1898, and again in 1914. This was spread upon the plowed land in early spring and harrowed in.

The stock of organic matter in the soil has been maintained by turning under heavy crops, as follows: winter rye in 1901, buckwheat in 1912 and rye in 1913; and by introducing grasses and clovers, 1905 to 1907, and turning under a heavy growth of grass before late cabbage in 1908.

All fertilizers have been applied broadcast in early spring, and, except when the land was in grass, on the plowed surface and disked in.

[1] For the first two years potash-magnesia sulfate, 400 pounds; in 1899, high-grade sulfate, 400 pounds; in 1901, potash-magnesia sulfate, 400 pounds.

[2] For the first four years 250 pounds.

[3] Tobacco dust was used by accident in place of hoof meal in 1911.

[4] To all bone-meal plots an amount to make total organic nitrogen equal.

Phosphates compared and Rates per Acre.

Plot.	Materials supplying Phosphoric Acid.	Pounds per Acre.
1	None,	–
2	Arkansas rock phosphate,[1]	376
3	South Carolina rock phosphate,	376
4	Florida soft phosphate,	364
5	Basic slag meal,	538
6	Tennessee phosphate,[2]	296
7	None,	–
8	Dissolved bone black,	522
9	Raw bone meal,	404
10	Dissolved bone meal,	432
11	Steamed bone meal,	380
12	Acid phosphate,[3]	500
13	None,	–

[1] Apatite used in 1897–1905; Arkansas since 1908.

[2] Navassa phosphate used in 1897–1900; Tennessee since 1901.

[3] Owing to a clerical error in copying, which occurred in 1901, this phosphate was used only at the rate of 380 pounds per acre from 1901 to 1913, inclusive.

Crops Grown.

As already stated, the field had been continuously in grass for a long period of time previous to the beginning of this experiment. While in grass it had, during the latter part of this period at least, received moderate annual top-dressings of chemicals. The year previous to the beginning of the experiment it was plowed and planted to corn without fertilizer, with a view to noting the relative productive capacity of the different plots. The date of planting was June 27; the date of harvesting, September 26, the corn being in milk. The yields were as follows: —

Yields of Corn without Fertilizer, 1896.

Plot.	Gross Weight (Pounds).	Plot.	Gross Weight (Pounds).
1,	3,440	8,	2,905
2,	3,090	9,	2,885
3,	3,000	10,	3,555
4,	3,095	11,	2,915
5,	3,160	12,	2,990
6,	3,020	13,	2,640
7,	2,850		

It will be noted that with three exceptions the yields are quite uniform. Plots 1 and 10 are considerably above the average in productiveness, while plot 13 is about as much below.

The crops grown during the experiment in the order of their succession have been as follows: corn, cabbages, corn, oats and Hungarian grass (in 1900), onions, onions, cabbages, corn (ensilage), grasses and clovers seeded in spring (no crop harvested), hay, hay, cabbages, soy beans, potatoes, oats and alfalfa (badly winterkilled, 1911–12), buckwheat (turned under), corn and corn.

Many of the annual crop yields have been published in the reports of the experiment station, and certain averages only will be presented at this time. These will include an average for each crop on each of the three classes of phosphates into which those used somewhat naturally fall. The first class includes the natural mineral phosphates: apatite and Arkansas phosphate,[1] South Carolina rock phosphate, Florida soft phosphate and Navassa and Tennessee phosphates;[2] the second class includes basic slag meal, raw bone meal and steamed bone meal; the third class, dissolved bone black, dissolved bone meal and acid phosphate.

The yields for the first two years have not been included in figuring these averages, as it is apparent that initial inequalities in productive capacity exercised a considerable influence in determining yields. It is not unlikely that such inequalities continued for some time (possibly they still continue to exercise some influence), but it is believed that the manner of computing increases due to the several phosphates previously described[3] has so reduced the influence of such inequalities that the averages of results extending over so long a term of years present a reliable basis for determining the relative crop-producing value of the different classes of phosphates.

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[1] Apatite from 1897–1905; since 1908, Arkansas.

[2] Navassa phosphate from 1897–1900; since 1901, Tennessee.

[3] See p. 148.

Increases per Acre in Crops produced by Different Classes of Phosphates.

	Natural Mineral Phosphates.		Basic Slag and Bone Meals.		Dissolved Phosphates.	
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.
Corn, three years, 1899, 1913, 1914: —						
Grain, ...	—1.06	-	8.03	-	9.96	-
Stover, ...	-	318.87	-	905.50	-	651.11
Hay, two years, 1906, 1907: —						
Hay, ...	-	398.30	-	615.55	-	753.33
Rowen, . . .	-	—131.00	-	97.33	-	350.67
Total, ...	-	267.30	-	712.88	-	1,104.00
Onions, two years, 1901, 1902: —						
Sound, ...	—30.60	-	143.60	-	136.73	-
Scallions, . . .	10.76	-	—19.23	-	—12.56	-
Cabbage, two years, 1903, 1908, ...	-	9,817.50	-	21,026.60	-	18,758.60
Oat hay, one year, 1900, .	-	231.70	-	1,324.40	-	1,520.00
Hungarian hay, one year, 1900, ...	-	166.70	-	—222.23	-	—253.30
Ensilage corn, one year, 1904, ...	-	—1,638.70	-	7,608.90	-	7,361.30
Soy beans, one year, 1910: —						
Grain, ...	.77	-	4.09	-	3.87	-
Straw, ...	-	290.56	-	794.67	-	776.00
Potatoes, one year, 1910: —						
Marketable, . . .	—10.70	-	16.40	-	26.90	-
Total, ...	—8.30	-	18.90	-	29.50	-
Oat and alfalfa hay, one year, 1911, . .	-	80.00	-	1,626.67	-	1,560.00
Alfalfa hay, one year, 1911,	-	91.70	-	244.40	-	73.30

The table makes it strikingly apparent that the natural mineral (rock) phosphates used in this series of experiments have produced much smaller average increases in crops than those of the other classes. For the purpose, however, of bringing out the relative effects more clearly the results have been figured on a percentage basis shown in the table below: —

Phosphate Field, 1899–1914. Increase over No-Phosphate Plots in Per Cent.

	Natural Mineral Phosphates.	Basic Slag and Bone Meals.	Dissolved Phosphates.
Corn, three years: —			
Grain,	—1.48	12.89	17.03
Stover,	5.83	17.74	13.22
Hay, two years: —			
Hay,	5.28	8.38	10.41
Rowen,	—11.34	8.64	31.88
Total,	3.08	8.42	13.24
Onions, two years: —			
Sound,	—17.75	137.35	160.10
Scallions,	12.86	—25.04	—16.56
Cabbage, two years (total),	116.01	288.30	278.32
Oat hay, one year,	4.22	27.62	33.63
Hungarian hay, one year,	4.30	—5.68	—6.46
Ensilage corn, one year,	—4.42	25.99	28.00
Soy beans, one year: —			
Beans,	2.54	14.38	14.00
Straw,	10.43	35.88	38.26
Potatoes, one year: —			
Marketable,	—4.00	6.84	11.72
Total,	—2.97	7.49	12.12
Oats and alfalfa hay, one year,	2.00	47.28	49.37
Alfalfa hay, one year,	11.49	32.35	9.40

1. The tabulation of averages shows that, with one exception, the percentage increases in crops of all kinds produced by the natural mineral phosphates are far smaller than those produced by the other classes of phosphates. The single exception is Hungarian hay grown as a second crop in 1900 without a second application of fertilizers. This exception, therefore, has no special significance in its bearing upon the relative efficiency of the classes of phosphates under consideration.

2. It will be noted that in a number of cases the averages for the slag and bone meals are higher than for the dissolved phosphates. It should be pointed out that in two respects the materials in the former class differ from those in the latter: (1) the slag meal furnishes some free lime and a considerable excess of lime in neutral combinations; (2) the bone meals supply some nitrogen in organic combinations.

It has been pointed out [1] that an attempt to equalize the organic nitrogen of the bone meals was made by the addition of hoof meal to the plots receiving other phosphates. It is generally held that the availability of the organic nitrogen in bone meals and in hoof meal is substantially equal, but in some experiments this has not seemed to be the case. No doubt the availability in both is much affected by fineness of grinding.

[1] See p. 149.

No effort was made to equalize the lime supply on the different plots, although the fact that the entire field was limed twice at the rate of a ton to the acre as already described [1] reduces the probability that the excess of lime in the slag exercised an important influence. The possibility, however, that the occasional superiority of the slag and bone meals may have been due to the factors referred to should not be overlooked.

3. It should be noted that the more soluble phosphates, while not increasing the stover of the corn crop so largely as the slag and bone meals, exercise a more favorable influence upon the production of grain.

4. This is doubtless, at least in part, due to the fact that the more soluble phosphates promote more rapid early growth and earlier maturity than do those less soluble.

(*a*) *More Rapid Early Growth.* — The marked effect of an application of soluble or quickly available phosphates upon the early growth of the corn crop has been many times observed. [2] We have made measurements only once in this series of experiments, viz., in 1914. These measurements were made on July 10, and indicate the extreme height from the ground to the highest leaf-tip. The figures are the averages of 40 plants in each plot, — equidistant individuals each in the fourth and seventh rows.

Height on July 10.

Plot.	Fertilizer.	Inches.	Plot.	Fertilizer.	Inches.
1	No phosphate, . . .	32.23	8	Dissolved bone black, .	42.15
2	Arkansas phosphate, . .	28.92	9	Raw bone meal, . .	40.02
3	South Carolina phosphate,	30.83	10	Dissolved bone meal, .	38.79
4	Florida soft phosphate, .	32.62	11	Steamed bone meal, . .	40.20
5	Slag meal phosphate, .	35.67	12	Acid phosphate, . .	42.05
6	Tennessee phosphate, .	32.99	13	No phosphate, . . .	29.69
7	No phosphate, . . .	30.96			

The great superiority of the soluble phosphates and the bone meals is clearly brought out by this table, while the average measurement indicates the slag meal to be materially superior to the natural phosphates in its effect upon the early growth.

(*b*) In favorable years varieties of corn suited to the locality attain maturity on all plots; but in years with summer temperatures much below the average, or those with early autumn frosts, a part of the crop fails to ripen completely. This was notably the case in 1913, in which year the thermometer fell to 31° at 6 A.M. on September 15. The percentages of soft corn were lowest on the slag meal and dissolved bone, —

[1] See p. 149.

[2] On our north corn acre acid phosphate has been used during the past twenty-five years at widely varying rates on different plots; in round numbers 1,100 pounds per acre on two plots, and 200 pounds per acre on two. During the first few weeks the growth on the plots receiving the larger application of acid phosphate is always far more rapid than on the other plots.

30 and 44 per cent., respectively; they were highest on the South Carolina rock, 87 per cent.; the average for all the natural rock phosphates was 63 per cent.; for the no-phosphate plots it was 71 per cent. The proportions of soft corn on the different plots were in my judgment affected by the physical differences in the soil of the plots, but there can be no doubt as to the general effect.

In 1914 the summer temperature was below the normal, but the crop was cut and shocked before frost. There was, however, some soft corn. The percentages were: no-phosphate plots, 12; natural rock phosphate plots, 9; slag, bone meal and soluble phosphate plots, 5.

5. The effect of the more soluble and available phosphates in promoting maturity is strikingly apparent, also, in the case of the onion crop grown in this series of experiments. The presence of scallions indicates imperfect maturity. Two onion crops have been grown in this experiment, — 1901 and 1902. Neither gave a satisfactory yield, and the proportion of scallions on all plots was much larger than normal, in my judgment, due in part to the fact that the field is not sufficiently heavily fertilized for the crop, and in part to the unfavorable physical characteristics which, as already pointed out, vary considerably on the different plots. The greater proportion of scallions on the rock phosphates shown in the following table is the more significant for the reason that in the plots where these were used the physical conditions were more favorable than on the other plots. The steamed bone meal, dissolved bone meal and acid phosphate plots have not been used in computing the averages shown because of the very unfavorable soil texture of these plots for the onion. The fact that the acid phosphate had been applied in only about one-half the amount needed to furnish equal phosphoric acid constituted a second reason for the omission of this plot.

Proportion of Scallions in Onion Crop (Per Cent. of Total).

	No-Phosphate Plots.	Dissolved Bone Black, Slag and Bone Meal.	Natural Rock Phosphates.
1901, ...	15	7	15
1902, ...	59	29	66

6. The relation between hard and soft heads in the cabbage crops grown in these experiments points also to the conclusion that the more soluble and available phosphates promote rapid early growth and maturity. In all cases there have been more soft heads on the no-phosphate and the rock phosphate plots than on the others. The slag plot has been among the best in the quality, solidity and weight of the crop. Full details have been published and figures will not now be given.[1]

[1] For relative weights, soft and hard heads, see sixteenth annual report, Hatch Experiment Station, p. 136. For crop in other years see eleventh and twentieth annual reports.

Relative Profits on the Different Phosphates.

The results presented fully establish the facts of larger relative increases and in some instances superior quality of crops on the more soluble and available phosphates. Clearly, therefore, the use of such phosphates rather than the fine-ground natural rock phosphates is the part of wisdom, unless the cost of the latter is so much lower that they allow greater profit on their use than do the more soluble phosphates, in spite of the greater crop increases on the latter. The table gives the differences in value between the average annual crop increases and the average cost for the different classes of phosphates.

Gain or Loss per Acre in Crop Values compared with Cost of Phosphates.

	Natural Mineral Phosphates.	Basic Slag and Bone Meals.	Dissolved Phosphates.
Cost of phosphates,	$3 67	$3 70	$3 24
Corn, average of 3 crops, 1899, 1913, 1914: —			
Grain,	—$0 79	$6 02	$7 47
Stover,	95	2 72	1 95
Total,	16	8 74	9 42
Hay, average of 2 crops, 1906, 1907: —			
Hay,	3 19	4 92	6 03
Rowen,	— 79	58	2 10
Total,	2 40	5 50	8 13
Onions, average of 2 crops, 1901, 1902 (sound),	—15 30	71 80	68 36
Cabbage, average of 2 crops, 1903, 1908,	58 91	126 16	112 55
Oat hay, 1 crop, 1900,	1 39	7 95	9 12
Hungarian hay, 1 crop, 1900,	1 00	—1 33	—1 52
Total,	2 39	6 62	7 60
Ensilage corn, 1 crop, 1904,	—6 55	30 44	29 44
Soy beans, 1 crop, 1909: —			
Beans,	2 31	12 27	11 61
Straw,	87	2 38	2 33
Total,	3 18	14 65	13 94
Potatoes, 1 crop, 1910: —			
Merchantable,	—6 42	9 84	16 14
Small,	48	50	52
Total,	—5 94	10 34	16 66
Oats and alfalfa, 1 crop, 1911,	48	9 76	9 36
Alfalfa, 1 crop, 1911,	83	2 20	66
Total,	1 31	11 96	10 02
Annual average,	$6 21	$36 23	$34 57

The results shown in this table are overwhelmingly conclusive on the point under discussion. The values of the crop increases in all instances exceed the cost of phosphate many times more on the more soluble and available materials than on the natural rock phosphates. The latter afford, therefore, far lower profits on their use than the former.

Cumulative Effect.

The advocate of the use of the rock phosphates may at this point urge that while such phosphates are at first less effective than the more soluble and quickly available materials they will ultimately fully equal the latter. This series of experiments has now continued eighteen years, and it would seem that this result should have been already realized. This has not been the case. The more soluble phosphates, bone meal and slag, still annually exceed the rock phosphates greatly in their effect on crop yield. Such excess, so far as can be judged, is still as great as at any earlier period. The corn crop affords the best chance of comparison, having been grown in 1899 and in 1914. The increases in crop per acre in the two years are shown below: —

Corn Crop — Increases per Acre, with Different Phosphates.

	Natural Rock.		Slag and Bone Meals.		Dissolved Phosphates.	
	Grain (Bushels).	Stover (Pounds).	Grain (Bushels).	Stover (Pounds).	Grain (Bushels).	Stover (Pounds).
1899, . . .	—2.410	113.3	1.27	—127.8	5.03	—493.3
1914, . . .	—0.175	243.3	13.27	1,808.9	15.37	1,460.0

These figures show greater increases in the corn crop on all classes of phosphates in 1914 than in 1899. Such increases, however, are insignificant for the natural rock phosphates, while for the slag, bone meals and soluble phosphates they are large. The latter excel the rock phosphates in 1914 in much greater degree than in 1899. The conclusion, therefore, seems justified that the natural agencies at work in this soil are not in any marked degree increasing the availability of the natural mineral phosphates. In the eighteen years during which this series of experiments has continued we have supplied 1,728 pounds of phosphoric acid per acre to the soil of these phosphate plots.[1] In the crops harvested from the rock phosphate plots, supposing them to have been of average composition, we have removed about 450 pounds. There has therefore been a large excess of phosphoric acid applied (about 1,275 pounds per acre), and still the amount available is insufficient to give maximum crops. The yields are far below those obtained on the slag, bone meals and dissolved phosphates.[2]

It is well understood that a large proportion of organic matter in the soil is favorable to the activity of the raw phosphates. In commenting on the results obtained in these experiments in his book "Soil Fertility

[1] Two exceptions have been noted, p. 150: plot 2, on which the shortage is 192 pounds, and plot 12 on which it is about 240 pounds.

[2] These also must have furnished phosphoric acid in much larger quantities than have been removed in the crops.

and Permanent Agriculture,"[1] published in 1910, Dr. Hopkins says: ". . . no provision was made for maintaining organic matter in the soil."

In view of the facts that a heavy crop of winter rye was plowed in in 1901, and after three years in hay (1905–07), a heavy growth of grass before late cabbage in 1908, it is believed the supply of organic matter had been well maintained. Certainly in our experience we have not only fully maintained, but actually increased, productiveness on soils of similar character by use of fertilizers only, under systems of management less favorable to the maintenance of the humus content. It is not believed there could have been a shortage of organic matter in the soil of these plots at the time when Dr. Hopkins wrote. Wishing, however, to create conditions as favorable as possible to the action of the raw phosphates, two heavy green manure crops have since been grown and plowed in, — buckwheat in 1912 and winter rye in 1913. It has been shown that in spite of this treatment not only is the increase in crops from the raw phosphates still less than from the others, but it seems to be falling still further behind.

INDIRECT OR SECONDARY EFFECTS.

The no-phosphate plots in this series of experiments have given crops which, as shown by calculation on the basis of average composition, have carried away nearly as much phosphoric acid as has been carried away in the crops of the phosphate plots. The totals of this element for these plots exceed the totals for the plots receiving no phosphoric acid, as follows: —

Phosphoric Acid in the Total Increases in Crops.

	Per Plot (One-eighth Acre) (Pounds).
Natural fine ground rock phosphates,	1.06
Slag and bone meals,	8.43
Dissolved phosphates,	8.63

If the crops on the phosphate plots have drawn upon the natural soil supply of phosphoric acid as largely as those on the no-phosphate plots, then the proportion of the phosphoric acid applied in these experiments which has been removed by the crops is extremely small, — indeed quite insignificant. As phosphoric acid is not subject to much if any loss from soils by leaching, it would seem that nearly all of this element which has been applied must still remain in the soil, even in those plots to which it has been applied in the more soluble forms.

In spite of this fact the use of the slag, bone meals and dissolved phosphates has given increases in crops which much more than cover the cost of the phosphates used as shown by the table on page 156. In view of this fact it appears probable that the benefits following their use must have been due in considerable measure, to indirect or secondary effects rather than to the direct plant-food action of the phosphoric acid they contained. One of these indirect effects — the stimulation to rapid

[1] Page 283.

early growth — has already been referred to.[1] There is considerable evidence which tends to show that there are several other indirect or secondary effects of importance.

Effect on Soil Acidity.

Most of the secondary effects are believed to be beneficial, but the question is frequently asked whether the use of dissolved (acid) phosphates will not exercise an injurious secondary effect through making soils sour. Those advocating the use of natural rock phosphates usually call especial attention to this effect. Thus, Hopkins says: "A third point in favor of raw phosphate, in common with bone and slag, is that it is free from acidity and has no tendency to injure the soil."[2] In the following sentence he asserts that acidity does develop from continued use of acid phosphate, but adds that it can be corrected at small expense by the use of lime.

The writer cannot point to results of chemical investigations in connection with his work which either prove or disprove the correctness of this assertion, that continued use of acid phosphate increases soil acidity. No such investigations have been undertaken. In some of his experiments, however, lime has been so applied as to afford opportunity to note the relative benefit as indicated by crop yield under otherwise similar conditions on plots over a long series of years, respectively, without and with application of an acid phosphate (dissolved bone black). If the dissolved bone black used continuously had increased acidity in any marked degree, it would follow that crops to which acid is toxic would show greater benefit from liming on the plots to which dissolved bone black was annually applied than on those plots not receiving it. In a long-continued series of soil test experiments,[3] where one-half of all plots has been limed, this

[1] See p. 154.

[2] "Soil Fertility and Permanent Agriculture," p. 242.

[3] This series of experiments was begun in 1890 and has continued to date. Nitrate of soda, dissolved bone black and muriate of potash have each been applied annually, as shown by the table.

Plot.	Materials applied.	Rates per Acre (Pounds).
1,	Nothing,	–
2,	Nitrate of soda,	160
3,	Dissolved bone black,	320
4,	Nothing,	–
5,	Muriate of potash,	160
6,	Nitrate of soda,	160
	Dissolved bone black,	320
7,	Nitrate of soda,	160
	Muriate of potash,	160
8,	Nothing,	–
9,	Dissolved bone black,	320
	Muriate of potash,	160
10,	Nitrate of soda,	160
	Dissolved bone black,	320
	Muriate of potash,	160
11,	Plaster,	400
12,	Nothing,	–

In 1899 one-half of all plots received an application of lime at the rate of one ton per acre; in 1904 a second application was made to the same halves at the rate of 2,300 pounds per acre; and in 1907 a third application at the rate of 1,000 pounds per acre.

has not been the case. The benefits following liming are with all crops greater without dissolved bone black than under otherwise similar treatment with it. In other words, the use of dissolved bone black appears to have decreased the necessity for lime.

Need of Lime as indicated by Relative Crop Increase after Liming.

	Muriate of Potash.		Nitrate of Soda and Muriate of Potash.	
	With Bone Black.	Without Bone Black.	With Bone Black.	Without Bone Black.
Corn, 1905: —				
Grain,	100	365	100	192
Stover,	100	1,363	100	36
Hay, four years, 1903, 1904, 1908, 1909,	100	207	100	101
Soy beans, three years, 1906, 1910, 1911: —				
Grain,	100	350	100	108
Straw,[1]	100[2]	32[2]	100[2]	90[2]

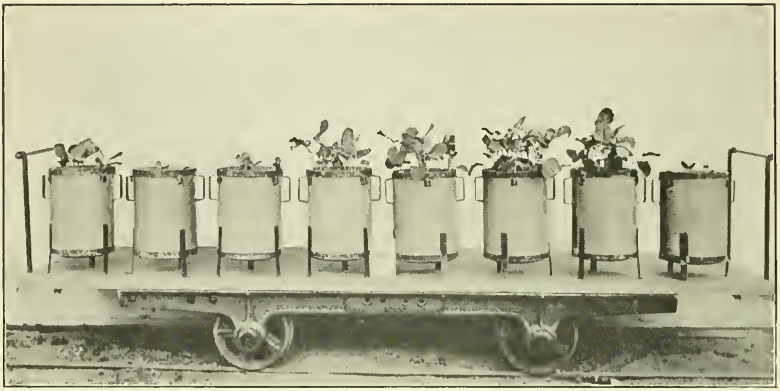
[1] Compared on the basis of relative decrease.
[2] Relative decrease where lime was applied.

It must be remembered in studying this table that the increases (or decreases) compared are, first, those under the treatments indicated by the headings of the first and second columns of figures; and second, those indicated by the headings of the third and fourth columns. The figures do not indicate the relations between these two pairs of plots (plots 5 and 9 and plots 8 and 10). It will be noticed that with one exception these results are perfectly concordant. The use of lime produces, with this one exception, a larger increase (or a smaller decrease) when used without dissolved bone black than when used with it. The exception is the effect upon the stover of the corn crop on nitrate of soda and muriate of potash. No explanation can at this time be offered; but it is made quite apparent by the smaller relative increases (and the larger relative decrease in one case) produced by lime without bone black when the latter is added to nitrate of soda and muriate of potash than when it is added to muriate of potash alone that the soda of the nitrate decreases the necessity for lime, — a fact which is generally understood.

It would seem to be thoroughly established by the results of these experiments that the use of an acid phosphate (dissolved bone black) at least has not increased the necessity for lime. On the contrary, it seems clear that the bone black has reduced this necessity.

Sulfur supplied.

It is recognized that considerable quantities of sulfur, in the form of calcium sulfate, have been applied to the plots receiving dissolved phosphates, and that the plots with which these have been compared have



Comparative test of phosphates, Dwarf Essex rape. Cubic capacity of pots, .545 cubic feet; weight of earth, about 17 kilograms at 12 per cent. moisture. All pots received equal and abundant nitrogen and potash. Where supplied, phosphoric acid per pot equals .41 gram. From right to left: no phosphate, dissolved bone black, acid phosphate, dissolved bone, steamed bone meal, South Carolina rock phosphate, Florida rock phosphate, basic slag phosphate (meal).

Comparative test of phosphates, Dwarf Essex rape. Cubic capacity of pots, .545 cubic feet; weight of earth, about 17 kilograms at 12 per cent. moisture. All pots received equal and abundant nitrogen and potash. Where supplied, phosphoric acid per pot equals .82 gram. From right to left: no phosphate, dissolved bone black, acid phosphate, dissolved bone, steamed bone meal, South Carolina rock phosphate, Florida rock phosphate, basic slag phosphate (meal).

received no such application. It may possibly be urged that this sulfur has been beneficial. This of course is possible, although numerous other lines of experiment carried on by the writer which afford opportunities for comparison fail to demonstrate any necessity for the application of sulfur.

Beneficial Secondary Effects from the Use of Soluble Phosphates.

Among secondary effects which appear to be generally admitted to follow application of soluble phosphates may be named the following: rapid early growth both of roots and tops, increase in tillering in grains and grasses, earlier and therefore often more perfect ripening, increase of the availability of certain soil constituents, and larger acquisitions of atmospheric nitrogen.

1. *Rapid Early Growth of Both Roots and Tops.* — Many observers have noticed the quick start which plants from seed make when dissolved phosphates have been applied. Attention has been called to the differences in rate of development of the corn crop in the experiment comparing different phosphates.[1] In numerous other experiments which have been carried out here similar differences have been observed. Especially striking have been the results obtained with rape and cabbages both in field and pot experiments. Differences about as great have been noted in the case of soy beans and millet.

The fact that the differences in early root development are perhaps even more striking than in early top development has not been demonstrated in our experiments, but Hall,[2] points out that Sir John Lawes called attention to this effect more than sixty years ago. He refers to a water culture which demonstrates it, and suggests that this effect accounts for the extraordinary results often following even small applications of soluble phosphates. He states that an application of half a hundred weight per acre of superphosphate in Australia to soils not signally deficient in phosphoric acid often doubles the yield of cereals, and expresses his belief that the result is due to the stimulating action of the phosphoric acid upon the young roots. He points out that this action is particularly important in that semi-arid country because as a result the plant quickly gets its roots down into the cooler and moister subsoil upon which the yield of the crop largely depends.

This stimulation of early root development must be a very great benefit under the conditions of our agriculture and in our climate. The crop which early develops an extensive root system — both deep and broad — can much better resist our frequent drouths than one whose roots develop more tardily. It is apparent, also, since it is known that roots by direct and intimate contact with soil particles exercise an important influence in supplying the plant with food, that the more extensive the root development the more largely the plant will be able to utilize the resources of the soil itself.

[1] See p. 154.

[2] "Fertilizers and Manures," p. 140.

The stimulation to rapid early development under discussion is especially important in the case of all crops with which it is for any reason unusually difficult to secure a perfect stand, whether from a habit of growth naturally slow and feeble at first, or from the fact that the seedlings are peculiarly subject to insect injury. The beet is an example of the first; the Swedish turnip of the second. In the cultivation of either table, sugar or mangel beets, and of all crops of the turnip or cabbage family, the use of soluble phosphates is highly important to enable them both to outgrow weeds and to withstand the attacks of flea beetles and aphids.

2. *Increase in Tillering of Cereal Grains.* — As cereal grains are quite unimportant in our agriculture no direct observations which demonstrate that the cereal grains tiller or "stool" more freely when soluble phosphates are applied have been made in our experiments. There seems, however, to be no doubt of the fact. Hall asserts it in the following words: "Both in the field and in pot experiments the phosphoric acid has a great effect in promoting the formation of adventitious buds, so leading to the tillering of the plant."[1] The beneficial effects of phosphates in top-dressing for hay are very likely associated in part with a similar effect, which should mean a closer turf and a thicker and heavier yield. The millets and Hungarian grass should, it would seem, show a similar influence.

3. *Earlier and More Perfect Ripening.* — The facts that in our experiments the more soluble phosphates have produced a larger proportion of sound and perfectly ripened corn and a larger proportion of well-ripened onions than the natural rock phosphates have been pointed out.[2] The more soluble phosphates in these experiments have also produced much the larger proportion of hard (mature) heads of cabbage. The fact that soluble phosphates in abundance favor perfect and relatively early maturity has been too often observed and is too well known to need demonstration.

With any crop, therefore, subject to possible frost injury in autumn, a free use of the more soluble and available phosphates should be the rule. In the case of garden crops, also, for which the price is usually much higher for the earliest product, the rule should be the same. A single day with such products as peas, sweet corn, tomatoes and many others which might be mentioned often means the difference between a large profit and a price which perhaps barely covers cost. The gardener, other things being equal, who uses soluble phosphates within reasonable limits most freely will be first in market with his product. No amount of previous use of natural rock phosphate can produce the same effect, for the phosphoric acid of these is not sufficiently soluble to exercise the required stimulation.

The superior color of fruits — especially of the apple — produced by trees in soils to which available phosphates have been freely applied is

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[1] "Manures and Fertilizers," p. 139.

[2] See pp. 154–155.

doubtless only a special illustration of this hastening effect on the ripening process. This effect on color has perhaps most frequently been attributed to the application of basic slag meal. It is, of course, understood that many other conditions also affect color.

4. *Effect on the Availability of Soil Constituents.* — That the action of the soluble phosphates in the soil increases the availability of some of the important soil constituents seems to be generally held. This is a point which has not been made the subject of special investigation here. That it will make it possible for the plant to draw more largely upon the soil because of the increase in root development which it causes has been pointed out.[1] Aside from this it is believed that the soluble phosphates exert a direct chemical effect which results in bringing some of the soil constituents more largely into solution. All soluble phosphates contain calcium sulfate (land plaster), and this compound is held by many to be the constituent of acid phosphate most active in decomposing the complex silicates of the soil and rendering the potash they contain soluble and available to crops. Long-continued experiments in the use of land plaster, which have been connected with soil tests continued for twenty-six years have not given very material increases in crops which respond in marked degree to an application of muriate of potash alone. The average increase in 13 corn crops grown in this soil test during the twenty-six years, due to the annual application of muriate of potash at the rate of 160 pounds per acre, has been 27 bushels, while the average increase due to the annual application of plaster at the same rate has been 2½ bushels. It seems clear that had the plaster exercised a very important influence in making the potash of the soil (present in this case in very large amounts) available there must have been a larger increase in the corn crop following its use.

The use of superphosphate has been shown to be favorable to nitrification,[2] and must therefore increase the availability of the organic nitrogen-containing soil constituents.

It has been asserted that some of the constituents of acid phosphate act as catalytic agents in the soil, and by their action render soil constituents available; but that this is the case does not appear to have been fully established. On the whole, therefore, it seems to the writer that the direct chemical influence of soluble phosphates as affecting the availability of soil constituents is less important than the other secondary effects which have been considered.

5. *Larger Gain of Atmospheric Nitrogen.* — It has been demonstrated that the activity of bacteria which have the ability to fix atmospheric nitrogen in the soil is increased by the application of superphosphates, and that as a consequence more nitrogen is brought within reach of the crop and a larger yield usually obtained.[3]

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[1] See p. 161.

[2] Abst. E. S. R., Vol. XXVIII., p. 216: Patterson & Scott Jour. Dept. Agr. Victoria, 10 (1912).

[3] Abst. E. S. R., Vol. XX., p. 621: Löhnis & Pillai, Centbl. Bakt. 2 Abt. 20 (1908), No. 24–25.

CONCLUSIONS.

The principal points which have been presented that have a bearing upon the questions affecting the need and selection of phosphates will now be summarized. It is believed all are either well grounded in general knowledge and experience, supported by results of our own experiments reported in earlier pages, or established by the experiments of others.

1. The products chiefly sold from Massachusetts farms contain relatively little phosphoric acid; potash is contained in them in far larger proportion, usually from four to six times as much.

2. Most farmers use purchased stock or horse feeds rich in phosphoric acid, and thus greatly enrich the manure made in that compound.

3. Phosphoric acid is subject to much less waste from accumulating manures under usual conditions than potash.

4. The crops grown in our farm, garden and orchard practice all take from the soil far more potash than phosphoric acid.

5. The fertilizers in general use for the past fifty years have supplied far more phosphoric acid than potash.

6. Phosphoric acid is subject to extremely little loss from soils by leaching.

7. It seems clear from the preceding statements that under our system of agriculture our soils are not being depleted in phosphoric acid.

8. Chemical analysis of our leading soil types by conventional methods shows that the percentages of acid soluble phosphoric acid and potash are usually nearly equal; averages for the State, phosphoric acid, .214 per cent.; potash, .252.

9. If all of these compounds found in our average surface soil by conventional methods of analysis could be utilized —

The phosphoric acid would (according to crop) last from ninety-two to eight hundred years.

The potash would (according to crop) last from forty-two to two hundred and ninety years.

10. The total potash in the surface soil very materially exceeds the total phosphoric acid, and acid soluble potash is usually much more abundant in subsoils than phosphoric acid.

11. In spite of the relatively greater stock of total potash in soils than of total phosphoric acid, an application of the former in soluble forms in fertilizers has produced larger crop increases than has a similar application of phosphoric acid for the following: asparagus, potatoes, corn, hay, clover and soy beans. The only crops giving larger increases on phosphoric acid are crucifers (turnips, cabbages, etc.).

12. The results of hundreds of experiments at this station and in various parts of the State indicate that phosphoric acid is not the key to "permanent" (successful and profitable) "agriculture" in Massachusetts. It is not usually the element *in minimo*. Potash, as measured by crop requirements, is more often *in minimo*, and determines the yield.

13. The phosphoric acid capital in our soils is certainly not too large; doubtless it should in many cases be increased. Phosphates should be used in our agriculture, and the question whether the natural rock phosphates should be employed is an important one.

14. In experiments which have continued eighteen years, in which various fine-ground mineral phosphates, bone meals (raw, steamed and dissolved), slag meal, dissolved bone black and acid phosphate have been compared on the basis of equal annual liberal application of phosphoric acid, the results have been highly unfavorable to the natural mineral phosphates with all important crops.

15. The percentage increases (of all crops, 1899 to 1914, inclusive) show the following averages: —

	Per Cent.
Natural mineral phosphates,	9.13
Slag and bone meals,	42.24
"Dissolved" phosphates,	44.85

16. The "dissolved" phosphates are much more favorable to rapid early growth than the natural mineral phosphates.

17. The "dissolved" phosphates favor ripening, as shown by the smaller proportions of immature product, especially with corn, onions and cabbages.

18. The increases in crops produced by the slag, bone meals and "dissolved" phosphates exceed cost of the materials in much greater degree than is the case with the natural mineral phosphates. The average figures are, per acre: —

For natural mineral phosphates, annually,	$6 21
For slag and bone meals, annually,	36 23
For "dissolved" phosphates, annually,	34 57

19. The natural mineral phosphates gave yields after eighteen years' continuous use, yet more inferior as compared with the dissolved phosphates than in the earlier years. The increases for the corn crop are, per acre: —

	Bushels.	
	1899.	1914.
Natural mineral phosphates,	—2.41	—0.175
Slag and bone meals,	1.27	13.270
"Dissolved" phosphates,	5.03	15.370

20. It is clear that the natural agencies active in the soil in these experiments act upon the mineral phosphates with extreme slowness, in spite of the fact that large amounts of organic matter have been incorporated with it by the growth and turning under of green crops.

21. The fact that increases in crops, even on the dissolved phosphates, account for only a very small proportion of the total phosphoric acid applied — less than 10 pounds out of 216 per plot — indicates that the favorable effects were due chiefly to indirect causes.

22. The dissolved phosphates greatly stimulate early root and top development. This action is of great importance in enabling the crop to draw more largely upon the soil both for water and food, and in enabling some crops to resist insect injury.

23. Dissolved phosphates are reported to favor tillering (stooling), and this means a thicker growth of grains, grasses and millets.

24. Dissolved phosphates favor early and perfect ripening, and are therefore much to be preferred where earliness is desirable and in case of crops liable to autumn frost injury.

25. Dissolved phosphates, chiefly through the activity of the calcium sulfate which they contain may somewhat increase the availability of soil potash.

26. The use of dissolved phosphates has been shown to be favorable to nitrification, and to larger gain in atmospheric nitrogen acquired through the activity of soil bacteria.

27. Finally no injurious secondary effects are known to be associated with any reasonable use of dissolved phosphates. Our experiments indicate that they do not increase the necessity for the use of lime.

Massachusetts farmers, gardeners and orchardists are advised against the general use of raw rock phosphates. In so far as they are needed in our agriculture the phosphates employed should be the more soluble and available kinds, such as acid phosphate (dissolved rock), dissolved bone, basic slag meal and bone meals. The dissolved forms are advised for a quick start and early maturity. The mixed fertilizers upon our markets usually contain a large proportion of phosphoric acid chiefly in soluble and available forms. The station bulletins show their character. Those high-grade fertilizers with a large proportion of water-soluble phosphoric acid will be most favorable to a quick start and early maturity.

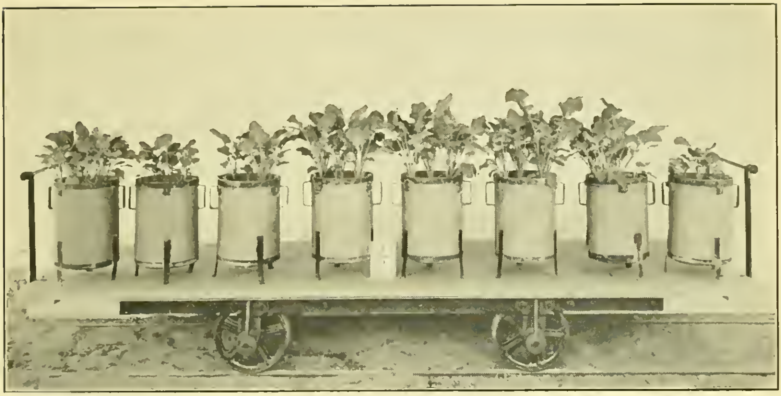
Natural rock phosphates are unadapted to the conditions of our agriculture, and their use will, with most of our crops and on most soils, give highly unsatisfactory results. What is needed in our agriculture is frequent (in case of many of our hoed crops, annual) applications of dissolved or quickly available phosphates.

Relative Phosphate Needs of Different Crops.

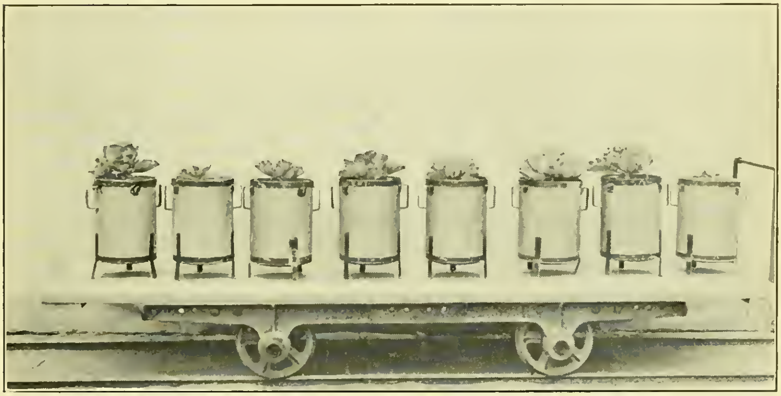
Our experiments indicate the use of phosphates to be especially necessary with all cruciferous crops (cabbage, turnip, cauliflower, Brussels sprouts, rape, etc.).

The onion also, especially if inclined to production of scallions, needs heavy applications of available phosphates.

For crucifers and onions in connection with materials supplying nitrogen and potash, 1,000 pounds per acre of a good acid phosphate, or an



Comparative test of phosphates, Dwarf Essex rape. Cubic capacity of pots, .545 cubic feet; weight of earth, about 17 kilograms at 12 per cent. moisture. All pots received equal and abundant nitrogen and potash. Where supplied, phosphoric acid per pot equals .44 gram. From right to left: no phosphate, dissolved bone black, acid phosphate, dissolved bone, steamed bone meal, South Carolina rock phosphate, Florida rock phosphate, basic slag phosphate (meal).



Comparative test of phosphates, cabbage. Cubic capacity of pots, .545 cubic feet; weight of earth, about 17 kilograms at 12 per cent. moisture. All pots received equal and abundant nitrogen and potash. Where supplied, phosphoric acid per pot equals .56 gram. From right to left: no phosphate, dissolved bone black, acid phosphate, dissolved bone, steamed bone meal, South Carolina rock phosphate, Florida rock phosphate, basic slag phosphate (meal).

equivalent of available phosphoric acid in a good mixed fertilizer, is usually desirable.

The yields of corn and potatoes seem to be in general less dependent upon applied phosphoric acid, but in the more soluble forms a fair amount is desirable, especially where early maturity is an object.

Grasses are affected relatively little by phosphates; clovers are somewhat more responsive, but in top-dressing mowings and pastures the proportion of phosphoric acid should be kept relatively low. Three hundred to 500 pounds per acre of acid phosphate in connection with potash and nitrogen materials, or an equivalent in a complete mixed fertilizer rich in nitrogen, will usually suffice in top-dressing mowings. Slag meal will be especially suitable where a large proportion of clovers is desirable, or in top-dressing soils which are moist and rich in organic matter. It seems also peculiarly adapted for use in connection with potash as a top-dressing for pastures, bringing in the more desirable grasses and white clover. The usual range in quantity needed appears to be between about 500 and 600 pounds per acre.

In orchard management phosphoric acid seems to favor both fruitfulness and good quality, and basic slag meal is in general favor among those who have tried it. This material in orchards, as in mowings and pastures, peculiarly favors clovers and other legumes, and thus indirectly reduces the necessity for nitrogen manuring. It does not, of course, materially affect the need for potash.

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